MAY 14 1908

SCIENTIFIC AMERICAN SUPPLEMENT. No. 1689

Entered at the Post Office of New York, N. Y., as Second Class Matter.
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Published weekly by Munn & Co. at 361 Broadway, New York.

Charles Allen Munn, President, 361 Broadway, New York.
Frederick Converse Beach, Sec'y and Treas., 361 Broadway, New York.

Scientific American, established 1845.
Scientific American Supplement, Vol. LXV., No. 1689.

NEW YORK, MAY 16, 1908.

Scientific American Supplement, $5 a year
Scientific American and Supplement, $7 a

FIG. 1.—ONE OF THE CUTTING SHEDS.

FIG. 2.—MACHINE PRODUCT READY FOR REMOVAL TO CUTTING SHEDS.

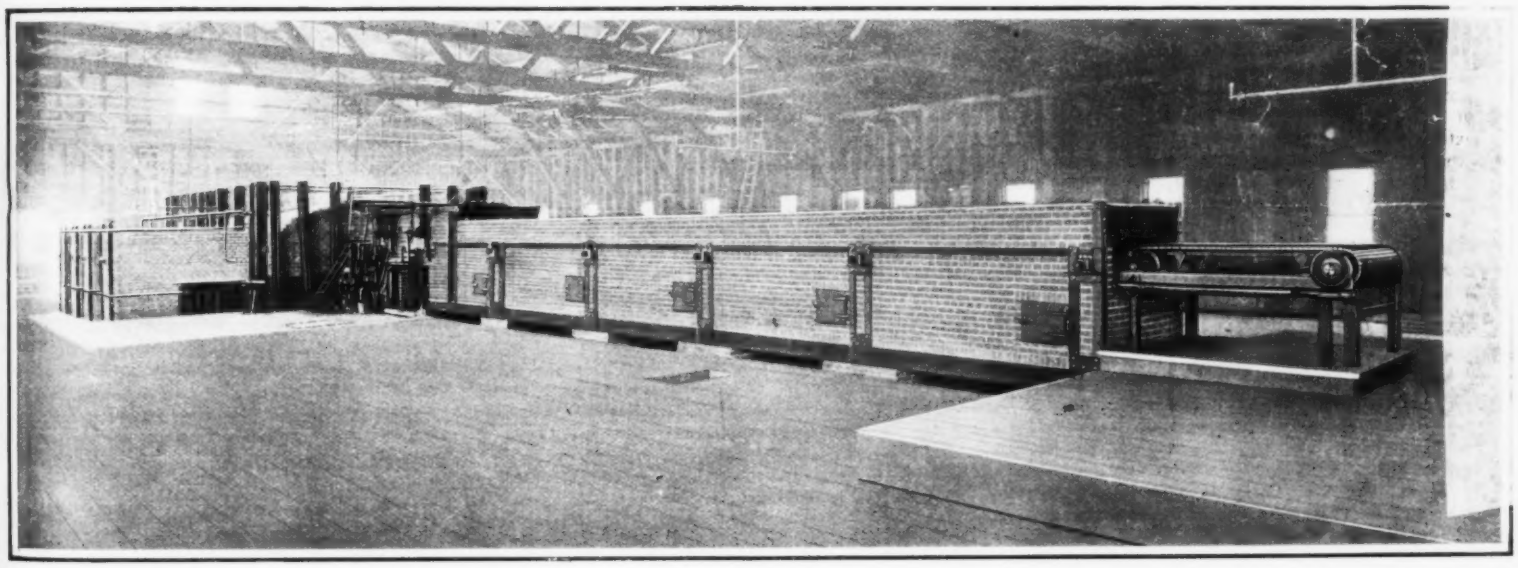


FIG. 3.—COMPLETE VIEW OF FURNACE, MACHINE, LEHR, AND CUTTING TABLE.

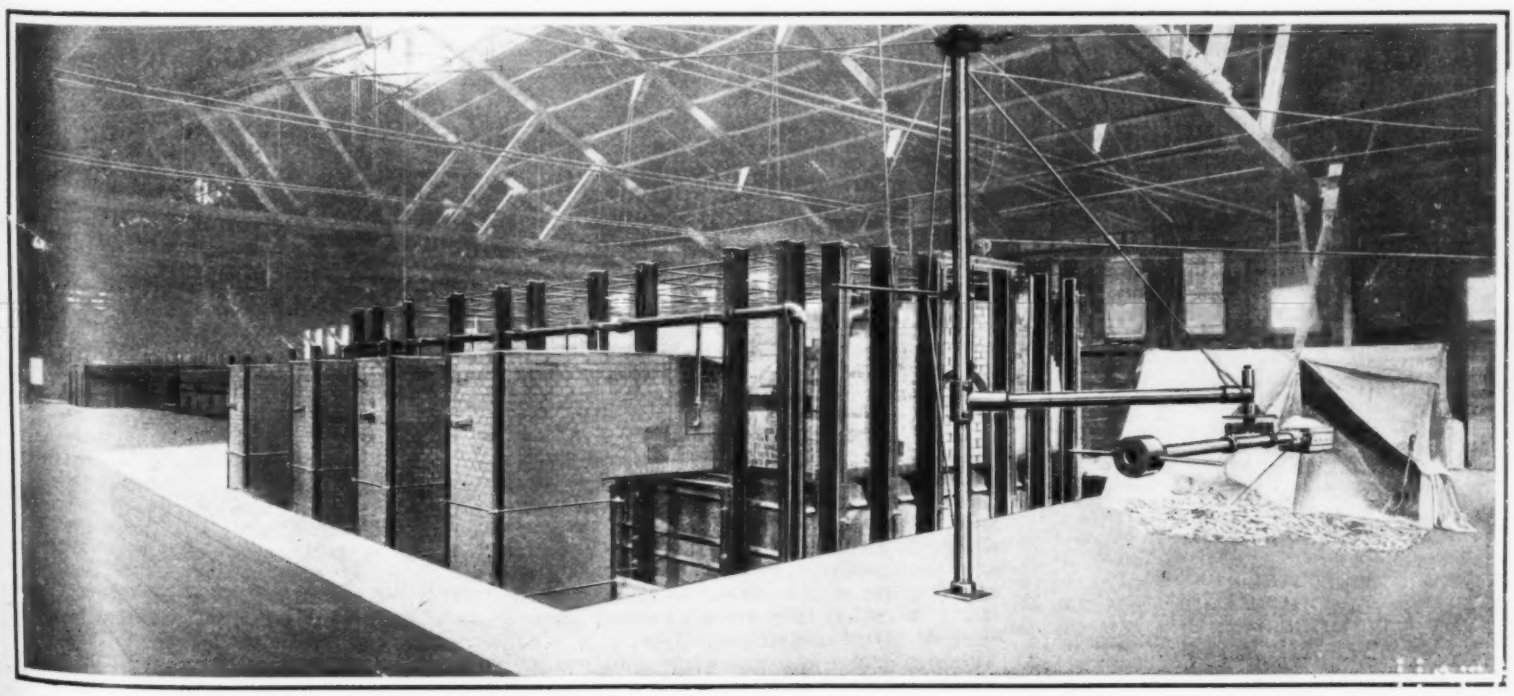


FIG. 4.—FILLING END OF GLASS MELTING TANK, SHOWING BATCH AND CHARGING MECHANISM.

THE COLBURN WINDOW GLASS MACHINE.—[SEE PAGE 312.]

MALLEABLE CASTINGS BY A NEW PROCESS.

MELTING WROUGHT SCRAP IN THE CRUCIBLE AND IN THE OPEN HEARTH FURNACE.

AT the November and December meetings of the West of Scotland Iron and Steel Institute a paper was under discussion, presented by E. C. Ongley, under the title, "The Production of Malleable Castings by the Fusion of Wrought Iron in Crucibles." There was some dissent from the statements of the author, and exception was taken to the fact that some details of the process were not divulged. However, since the chief raw material employed is said to be "wrought iron," while the resulting castings do not require to be annealed, and have desirable physical properties, the paper is of interest, albeit the author replied but generally to direct requests for light on the matter of the additions made after the melting of his mixture and preliminary to pouring the molds. It would seem, moreover, that the old materials made use of are largely steel to begin with, in spite of the designation "wrought iron" used by the promoters of the process. A synopsis of the paper prepared by the Iron Age is given below, together with the substance of the facts developed in the discussion:

MALLEABLE CASTINGS FROM THE CRUCIBLE.

The new process has for its object the production of a metal for making castings, with the properties of steel; also of forged iron, but unlike the latter in that when fused it can be cast into molds, producing castings with a carbon percentage of 0.05 to 0.07. The raw material, scrap and wrought iron, consisting of scrap nails, bolts, chippings of plates and punchings, is filled into crucibles of plumbago with a cover, and is then placed on a disk pedestal resting on the fire bars of the furnace, which is then filled with coke. The four-cornered shaft furnace has a double iron casing, and is lined with firebricks; the blast is heated by circulating in the hollow space round the hot furnace, which is placed in a pit. The process of fusion of the first charge requires about two hours from the time of lighting up, whereas the following charges are ready for casting in about one and one-half hours. The standard furnace can take four crucibles of 100 pounds capacity each, and with four charges daily the weekly output of one furnace would be about three tons of castings, as castings, or in the shape of ingots. The waste is very inconsiderable, but the marketable product is about 65 to 75 per cent of the raw material, the gates and runners, which can be remelted, making up the 100 pounds of each crucible. When the melting process is completed, which can be ascertained by a testing rod after the crucible cover has been taken off, the molten material appears quite white, sometimes slightly boiling; but on the addition of certain materials it is at once quieted, and must be then poured into the mold with as little delay as possible, as the high temperature of about 2,700 deg. F. of the metal is an essential feature for the success of this process. The castings do not require annealing.

The sand of the molds, by a suitable addition of refractory materials, ganisters, etc., is prevented from burning on, so that the castings have a smooth, clean surface, and are also sound, free from blowholes, and perfectly homogeneous.

The temperature of 2,700 deg. F. must be uniformly maintained to secure the fluidity of the metal, so that it can run out into the finest lines down to 3/16 inch of any pattern, of machine parts, of boiler fittings, valves, etc., which can thus be made lighter than is possible with any other metal with such high tensile strength.

The cost of production is low, as it depends on the price of raw material, which is a by-product of engineering work, and which consists entirely of waste and scrap of malleable iron and mild steel containing 0.05 to 0.2 carbon percentage; besides this, the cost of the plumbago crucibles—which are good for four or five charges—the consumption of fuel, the wages of the furnace attendant, the additions and general expenses, make a total cost of about $50 to $60 per ton for the material as it runs out of the crucibles into the molds. The wages for molding have to be added.

Some results of tests are as follows:

	Tensile Strength per Square Inch.	Elongation, Bars of 3½ Ins. Per Cent.
Forgeable quality	22 tons	32.3
Forgeable and weldable quality	23 tons	32.2
Mild steel	24 tons and more	24.3
Hard steel	45 tons and more	19.5 to 12

On being machined it is found that the surface of these castings does not consist of a hard skin, but is simply of a sound homogeneous material, offering no more difficulty to the cutter or cutting tool operating on it than when a forging is machined. The work of machining is much reduced as compared with forgings, as the margin for tooling can be made very small in the pattern. A shrinkage of 2 per cent has to be allowed on the patterns. The tensile strength can be varied to suit requirements, by adjusting the composition of the additions to the molten metal. The castings are used for marine engines, boiler mountings and motor car parts. Their high permeability has brought them into use for dynamo work, having higher capacity than cast iron with reduced weight.

The cost of 1 hundredweight of metal from the crucible is given as follows. To this is to be added the cost of molding.

	s.	d.
Wrought iron and mild steel scrap with 0.05 to 2.25 per cent carbon	3	6
Cost of crucibles	2	6
Coke consumption, 2 cwt.	2	6
Wages	1	6
Furnace expense	0	6
Cost of blast	0	6
Additions	0	6
Total	11	6

MALLEABLE AND STEEL CASTINGS BY A SPECIAL OPEN HEARTH PROCESS.

Castings are produced on the most favorable commercial scale in the open hearth furnace by melting wrought iron scrap in connection with a special process for the treatment of the molten metal. These castings can be large or small, of soft ingot metal with all the properties of wrought iron, ranging up to hard steel, suitable for parts of machinery subject to heavy wear, or for tools, milling cutters, drills, stamps and dies, valves, gear wheels, etc. The raw material consists chiefly of wrought iron scrap, to which a slight addition of hematite pig iron is made up to 15 per cent, to procure the quality to be produced. The oxides which are developed in the liquid bath are reduced by a corresponding addition of deoxidizing materials; when the liquid metal is ready for casting, certain additions, which constitute the special process, are made to the molten metal in the furnace. The additions are made just before the molten metal is to be tapped, so that its quality can be decided on or changed just before the metal leaves the furnace. By this means the important advantage is secured that castings can be produced at the very last moment to suit urgent requirements, without causing any inconvenience or increased cost. The special process enables the production of castings for all purposes, soft and tenacious, like best wrought iron for shipbuilding, for stern posts, etc., as well as the production of mild steel for machinery, and of steel suitable for tools and other purposes.

The metal is dense and of homogeneous structure, free from blowholes and sponginess. It has been tested with the following results:

Wrought iron quality, tensile strain 20 to 30 tons per square inch; elongation, 18 to 27 per cent; contraction, 46 to 52 per cent.

Mild and hard steel, tensile strain 25 to 50 tons per square inch; elongation, 10 to 28 per cent; contraction 20 to 30 per cent.

The following items show the actual cost of production of this metal up to the pouring of the mold for 1 hundredweight:

	s.	d.
Wrought iron and mild steel scrap, bolts nails, etc.	2	6
Hematite pig iron	1	6
Deoxidizing materials	0	6
Coal, attendance, etc.	2	0
Additions	1	0
Total cost for 1 hundredweight	7	6

The average cost would be $35 per ton of the metal as it leaves the furnace to be run into the molds. This cost is reduced to $15 and $20 per ton, when the production is on a large scale. The molds have to be coated with a wash of refractory materials to make them stand the high temperature of the metal without being burnt on, so that the castings have a clean and smooth surface. The cores are also specially treated so that they easily part from the castings, thereby insuring a clean surface to the hollow spaces of the castings as well as to their outward surface.

DISCUSSION.

Some skepticism was expressed by those who discussed Mr. Ongley's paper as to any revolutionary features of his process. More light was asked on the matter of the additions. The alloying of iron with aluminium or with silicon was familiar, one of the speakers urged, so that if these alloys were used the process in this respect presented no novelty. The president of the institute said that the heat of 2,700 deg. referred to was not unusual. Referring to the low carbon and low silicon material employed in the process, which had been spoken of in the paper as malleable steel or malleable iron, the speaker thought it was rather malleable cast iron. While not employing the process described in the paper he had used scrap with a low percentage of graphite carbon, phosphorus and sulphur and melted it in a cupola. After annealing the product made first-class malleable castings, almost like steel, which could be forged into tools. He questioned if more than this was done in the practice described.

Mr. Ongley, in reply to the comments of those who discussed his paper, said that the use of the process in connection with the open hearth furnace had gone on for six years and that eighteen plants in Germany were employing it, chiefly in making castings for motor car work. Answering the statement that the process was not novel, he said that no works in England melted wrought iron in pots, securing a temperature of 2,700 deg. In Sheffield they melted at about 2,000 deg. F. Several West of Scotland firms had sent representatives to Brussels to see the new process at work. The composition of the additions to the molten metal was not generally disclosed, as this was a commercial detail. The materials employed are aluminium, spiegel iron, nickel, molybdenum, vanadium, tungsten, silicon, wolfram, and various other metals known to those in the trade. The proportion of these materials used to the amount of molten metal was not stated, as the object of the paper was not to give full directions for applying the process. When he used the words "special ingredients," he took it for granted that the nature of the materials would be generally known to those engaged in manufacturing steel, and that they would also be aware that nothing of a secret or charlatan nature could have been meant. The furnace described enabled the high temperature to be obtained for keeping the molten metal fluid, and the materials mentioned are added to the metal for the purpose of keeping up its temperature and removing the gases in it. Sound castings as thin as 3/16 inch could be produced. The president's remarks on producing malleable iron from the cupola in Harrington refer only to the production of malleable castings, which have to be annealed before they can be used.

DENATURED ALCOHOL FROM CURRANTS.

AN interesting industrial experiment has been carried out in Greece the results of which have proved eminently satisfactory, and it is now undergoing extensive development. This is the manufacture of denatured alcohol from currants for lighting and power purposes. The fruit utilized for this purpose is that which is unsuitable for domestic purposes, so that the new industry will offer no serious competition or affect the prices of the commodity destined for consumption. As is well known, the currant-growing industry is the most important of the country, and is jealously guarded and preserved from the financial operations of any ring. The welfare of the industry is settled by the government in a privileged society having autocratic powers since it controls the production, distribution, and financial operations of the industry with government assistance whenever necessary. By this means shortages of supply attended with enhanced prices, corners, and other similar operations are entirely avoided. Naturally, prices are higher in periods of scarcity and lower in times of plenty, but the society endeavors to maintain regular prices as far as practicable. The work of this governing body is at times somewhat difficult, since they have to attend to the requirements both of the markets for consumption and those for manufacturing. Approximately 35 per cent of each year's crop, irrespective of its proportions, is set aside for manufacturing purposes. The former is the indifferent and unripe fruit and as such is sold at a much lower figure than that demanded for the domestic article, which is carefully picked over and selected. The result of this practice has been an increase in the quality of the fruit exported to foreign markets, since, whereas formerly the shippers mixed inferior and good fruit together with impunity such tactics are now impossible, for competent inspectors are deputed by the controlling society to the growing areas and supervise the selection so that only the best grades reach the exporters' hands.

Hitherto some difficulty has been experienced in the disposal of the inferior fruit delegated for manufacturing purposes, with the result that heavy accumula-

tions resulted. A syndicate then approached the government for the privilege of producing denatured alcohol from the residue. Through the energies of the late John Pesmazoglou, an eminent Hellenic financier, a concession for the purpose was secured and a company was formed with a capital of $1,158,000 to exploit the scheme. A contract was duly concluded with the privileged society controlling the currant industry by means of which the fruit for the purpose was purchased at a fixed figure. The new illuminant found instant favor among the Greeks, the manufacturers spared no effort to demonstrate the possibilities and advantages of the system, and to-day there is no country in the world in which this synthetic product is used upon such an extensive scale as in Greece. It is being used for both private and public purposes. Residences are equipped with facilities for illuminating, heating, and cooking, shops are fitted and streets are lighted therewith, contracts having been made with the municipalities for installing the requisite mains. The company has also sold lamps, effected the necessary modifications to adapt such as are at present used for petroleum oil to the requirements of the denatured spirit. They also encouraged its adoption for power purposes, and many stationary engines which hitherto were steam-driven or operated by oil or petroleum gas are now run on alcohol. By this means the company have been able to extend their business and to-day they have some 25,000 customers using the spirit for such purposes. The light supplied is of a brilliant intensity while it is odorless, thereby having distinct advantages over oil, petroleum, or coal-gas, and acetylene. While somewhat dangerous to handle, the consumers have been initiated into the safe methods of using it and as a result of such care and judicious instruction accidents are now of rare occurrence.

In addition to its greater intensity and brilliancy it has the further recommendation of being cheaper than other lighting systems, it being about half the price of petroleum. Whereas in Greece the latter costs 80 cents, the alcohol costs only 40 cents per gallon. Under the retention law the company started operations upon a reserve stock of currants representing over 100,000 tons, and as the yearly average of currants set aside each year for manufacturing purposes aggregates 300 tons, it is not probable that the demand for the spirit will exceed the supply for several years to come. Although under these circumstances it would be possible to distill a vast quantity of the denatured spirit for export markets, the manufacturers have decided against such developments.

WASHING AND COKING TESTS OF COAL.

SOME EXPERIMENTS MADE BY THE GEOLOGICAL SURVEY.

THE United States Geological Survey has recently published a bulletin giving an account of some experiments made for the fuel testing plant of the Survey by Richard Moldenke, A. W. Belden, and G. R. Delamater, the results of which experiments may be summarized as follows:

The necessary routine work in order to cover many coals permitted so few tests on each, and the supply of coal in many cases permitted only one test to be made on that particular coal. The data presented show the results obtained under the best conditions possible to one not conversant with the burning of these coals, based on observations made from time to time as coking proceeded. In future work it may be possible to vary conditions, make changes as they suggest themselves, and compare results on many different tests of the same coal and thus draw conclusions of a more definite nature. It is to be regretted that no comparisons can be made between beehive and by-product coke, but the nature of the work recorded and the facilities provided confined operations to ovens of the beehive pattern exclusively.

No data are given for compressive strength or height of furnace burden supported, as the results obtained show conclusively the worthlessness of these determinations. This conclusion was reached after careful attempts to obtain results on 1-inch cubes. Four cubes were selected from each coke made, care being taken to obtain pieces with no fracture and representing as nearly as possible the average of the coke. The cubes were cut by means of an emery wheel and guide, and although by no means perfect they were as nearly so as possible, and the two sides used in the machine were always parallel. The machine used for breaking was a Tinius Olsen patent machine of 10,000 pounds capacity and gave direct readings of the ultimate strength.

Only a few of these results, taken at random, are given, and these only to show their great variation and the worthlessness of this method of drawing conclusions. Illinois No. 16, test 10, 910 pounds, 1,330 pounds, 2,190 pounds, and 2,270 pounds; Indiana No. 4, test 6, 640 pounds, 790 pounds, 1,060 pounds, and 1,245 pounds; Kentucky No. 1, test 76, 880 pounds, 1,065 pounds, 1,920 pounds, and 2,570 pounds; Ohio No. 9, test 94, 535 pounds, 890 pounds, 1,170 pounds, and 1,600 pounds; Virginia No. 1, test 68, 740 pounds, 1,120 pounds, 1,280 pounds, and 2,060 pounds; West Virginia No. 16, test 49, 520 pounds, 1,500 pounds, 1,780 pounds, and 2,100 pounds.

The difficulty of obtaining a cube, or any number of cubes, to represent anything more than the piece of coke from which it is taken is so apparent that results pretending to show compressive strength of any amount of coke are worse than useless—in fact, misleading. Even if coke is selected the whole height of the charge and tests are made on cubes in number representing the number of inches the results still show only the strength of the one piece of coke from some particular part of the oven, and it is practically impossible to procure even approximately similar results from other pieces taken from different places. The condition of burning, the quenching either inside or out, and any number of factors which it is not possible to know, much less control, make different portions of the same oven vary greatly.

A simple calculation will show that coke with a compressive strength of 48 pounds will support the burden of any modern furnace; consequently this test gives no data of practical value. Moreover, there are so many other factors, such as action of heat and gases, attrition of coke against coke, against other ingredients of charge, and against the side walls, etc., that any calculation to show the burden-bearing capacity of the coke, even if it were possible to select cubes representing the whole charge, would be inaccurate if based simply on a compression test.

An endeavor was made to compare the different cokes by approximating the amount of breakage under conditions of present-day handling, showing the percentage of coke over 2-inch size that may be expected to reach the top of the charge in the blast furnace. Fifty pounds of each coke were selected, as nearly as possible representing the average size of the coke after handling at the ovens. This coke was dropped a distance of 6 feet onto a rigid (1-inch) iron plate. All pieces over 2 inches in size were weighed and again dropped, the operation being repeated three times.

The yield of coke appears to be increased and the amount of breeze reduced by preliminary crushing. Whether there is a limit to the degree of fineness, or whether a point may be reached beyond which finer crushing gives no appreciable improvement or has opposite effects, can not be determined from the present results; but the data available indicate that it would be economical to crush all coal before charging into the ovens, even though a coke of good quality may be obtained without this preliminary treatment. Fine crushing also appears to increase the strength of the coke and make the fracture less irregular, by the greater uniformity and distribution of the ash, but the weight per cubic foot is reduced. The strength of the coke is probably influenced by the amount, composition, and distribution of the ash, but the results so far obtained show no definite relations between these factors or their relative importance.

The matter of investigating the action of CO_2 on red-hot coke as determining its value for furnace work was thoroughly considered. The conclusion was reached that it was of no practical importance, as there are so many other factors in the blast furnace. In view of the fact that the gases in the furnace are mixtures of CO_2, CO, H, O, N, water vapor, and probably others, it appears that action of CO_2 is of little value unless the action of these other gases, either independently or in connection with CO_2, is known. An investigation of the action of CO_2 on red-hot coke, as a means of making comparison of hardness, is being made and gives evidence of yielding some positive results, but work along this line has not progressed far enough to draw any definite conclusions.

The loss of sulphur from coal to coke by volatilization varies with the different coals, depending on several factors, among which, in the order of their importance, are the condition in which sulphur exists in the coal, the heat of the oven, the rapidity of coking, and watering. The sulphur loss ranged from 20.79 per cent on Arkansas No. 1 (test 95) to 63.07 per cent on Illinois No. 29 (test 170), the average for all tests being 43.27 per cent.

GREEN AMMONIO-CITRATE OF IRON FOR PREPARING BLUE-PRINT PAPER.*

By RANDOLPH BOLLING.

IN order to get the best results in making blueprints, the photographer should sensitize his own paper, so that it will be perfectly fresh and do the printing in half the time. The formula for preparing the sensitizing solution is an exceedingly simple one, the only chemicals required being ammonio-citrate of iron and potassium ferri-cyanide. Unfortunately, there are several grades of ammonio-citrate of iron, and not all of these adapted for the purpose. If one buys it from a drugstore, the salt known as one of the "scale compounds" of iron is usually sold, and the ammonio-citrate of iron comes in shining black scales looking not unlike glue. If the bath should happen to be prepared from this compound, it will be found to be very unsatisfactory; it will show suspended matter (ferric hydroxide) and it will also be found very difficult to get the ammonio-citrate of iron in solution. The cause may be traced to the complex nature of the salt and its proneness to decomposition. For photographic purposes it must be freshly prepared, and it is then a light green color, very soluble in water, throws down no basic salts of iron, and produces a perfectly clear bath.

PROCESS.

The starting point in its manufacture is freshly precipitated ferric hydroxide. There are several ways of making this. One of the most convenient is to react on a soluble ferric salt with ammonia; if this is not at hand, dissolve steel borings or turnings in dilute nitric acid. Weigh 150 grammes of steel borings into a one-liter beaker, and add slowly 500 cubic centimeters of a mixture composed of one part strong nitric acid and three parts water, keeping the beaker cool by immersing it in cold water, as the action is energetic. After all the steel has dissolved, dilute the contents with 300 cubic centimeters of water. Ammonia water is now added, with stirring until the solution has a faint odor of ammonia. Allow the beaker to stand a few hours until the dense precipitate of ferric hydroxide has settled near the bottom. Then pour off the clear liquid, add hot water so as to fill the beaker, and stir again. Repeat this five or six times until all the soluble ammonium nitrate, a by-product in this reaction, has been more or less removed. Ferric hydroxide prepared in this manner from a nitrate solution of iron is to be preferred to the chloride because of the difficulty of removing all traces of chlorine, should the ammonio-citrate of iron be used in connection with silver nitrate in making silver prints. Nitric acid is also a more rapid solvent for steel than hydrochloric acid.

After decanting most of the wash water from the ferric hydrate, prepare a saturated solution of citric acid by dissolving the crystals in boiling water, using about 300 grammes. The ferric hydrate is now heated to boiling, and the hot citric acid solution added slowly to it with constant stirring. The solution gradually clears up as the acid reacts on the ferric hydrate, and exact neutralization is noted when the last of the brown precipitate disappears. The solution is now allowed to cool, and ammonia water added with constant stirring until the liquid smells strongly of ammonia.

It is now placed in shallow porcelain trays, and allowed to evaporate down on a hot-water or steam radiator or on a hot-water bath. It is noticed in this reaction that ammonia does not reprecipitate the iron in the hydroxide form. This is due to the formation of a double compound; the ammonio-citrate of iron and excess of ammonia does not decompose it. The evaporation can be carried on until the ammonio-citrate of iron becomes very thick and pasty. It is better to stop at this point and pack it immediately in glass bottles, taking the precaution to fill the bottle almost to the stopper, and then sealing the stopper with paraffin wax. This prevents decomposition, and preserves the salt as a light green soluble paste. If exposed to air for any length of time decomposition sets in, and the salts turn black, probably caused by reduction of the ferric salt to ferrous compounds. A good sensitizing formula for photographic printing paper for blue prints is as follows: Dissolve 105 grammes of ammonio-citrate of iron prepared as described above in 500 cubic centimeters of warm water, and add to this a solution prepared by dissolving 78 grammes of chemically pure potassium ferricyanide in 400 cubic centimeters of warm water. Stir well in

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

the dark room, and the solution is ready for use without filtering. It will coat approximately 300 square feet of paper. It is best to scale this formula to make just enough sensitizing solution, so as not to have any left over, as it soon decomposes. The paper will be found very sensitive to light, and the whites will wash out perfectly clear.

The stability of blue-prints and also the brilliancy is increased if the last changes of wash water are slightly acidified with a few drops of hydrochloric acid, which appears to have some chemical action on the Prussian blue of the print.

ELEMENTS OF ELECTRICAL ENGINEERING.—XVII.

TRANSFORMERS AND TRANSFORMER SYSTEMS.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1687, page 277.

By a "transformer" is meant an assemblage of iron core and two copper windings used for exchanging one alternating voltage for another. Various other names have been used to refer to the same thing, such as induction coils, inductoriums, converters, and secondary generators. In the necessary limitation of certain names to represent definite things, the first of these is now understood to mean the ordinary form of sparking or shocking coil; the second refers to the same device, but is seldom used; the third has a new qualification, to be explained in the next chapter; while the last is a historic name only.

Two things which a transformer, unaided, cannot do, are either to change alternating current into direct (or *vice versa*), or to change the frequency of the alternations. Apparatus which will actually do these things usually works in connection with transformers, but cannot be treated in this chapter. In this article the attempt will be made to explain not so much in what ways different manufacturers construct transformers, as to bring out prominently the essential principles involved in all of them, and also in a group as arranged or distributed upon a circuit. In no branch of engineering is an epoch more clearly marked that that which demonstrated the practicability of the transformer. Expensive and almost crushing

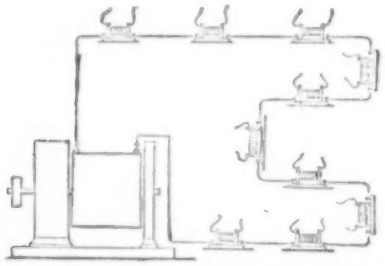


Fig. 75.—Gaulard and Gibbs's System of "Secondary Generators" in Series.

mistakes accompanied the pioneer experiments, but when once on the right track constructions of higher efficiency than the dynamo itself were possible, and the business of long-distance electric lighting and power transmission was rendered highly profitable.

The transformer system was first introduced into the United States in 1886; and to appreciate the significance of its advent and the opportunities before it, one has only to consider the limitations experienced by the low-tension direct-current systems, commonly typified by those using original Edison apparatus. Even though heavy copper conductors were used, it was found impossible to keep the voltage constant even over a single city block or group of business houses. It was therefore necessary for a station of this sort to locate in the close neighborhood of its largest customers, where real estate was limited and expensive, where the carting of coal and ashes must be by wagons in the street, where no condensing water was available, but where smoke, exhaust steam, noise, and vibration were apt to be declared nuisances. With the introduction of the three-wire system, allowing the use of double voltage, conditions were sufficiently improved to admit the economical lighting of lamps half or three-quarters of a mile from the station. Still the station managers regarded extended residence lighting as quite out of their reach. Meanwhile, series arc lighting, experiencing no difficulties from lengths of circuits, developed into a service that was then believed well-nigh perfect.

With the advantages of the high voltages and series connections realized in the arc lighting systems before them, Gaulard and Gibbs brought out in England, in 1882, the scheme diagrammatically represented in Fig. 75. In this it is meant to show an alternating current generator of reasonably high voltage, with its circuit extended through one of the windings of each of ten induction coils. These latter had straight cores of the well-known Ruhmkorff type, but with this difference, that both primary and secondary windings were composed of the same size of wire and of the same number of turns. These coils were to be placed at convenient points, and their secondary circuits then connected to rows of incandescent lamps, in the ordinary multiple method. In consequence of the surety of the same current passing through each primary, and incidentally energizing it, there seemed the surety

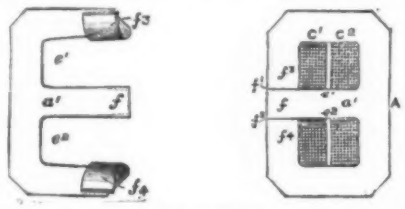


Fig. 76.—Sheet Iron for Westinghouse Transformer.

of each secondary generating the same electromotive force; therefore, however distant from the source, lamps would everywhere burn with the same brilliancy.

At a public exhibition in London, in 1883, two such induction coils were operated on a comparatively short line, but actually lighted lamps. Later in that year, four coils were placed at widely different points on a circuit 16 miles in length; and in the next year, at the Turin, Italy, exhibition, a primary circuit 50 miles in length was constructed. In all these cases, regulation of voltage for each particular load was effected by varying the number of secondary conductors, or by moving, in or out, the straight bundles of iron wire of which the core was composed. George Westinghouse (then Junior) was so impressed with the possibilities of this system that he bought the patent rights for this country, and at once sought to equip actual stations. An improvement in the efficiency of the induction coils was made by having the iron of the magnetic circuit continuous, instead of compelling the magnetic lines to go a long distance in air, but all the primary coils were still connected in series. Actual results were as crude and unsatisfactory as with the inventors' original apparatus. The fault was this, that the act of turning on or off a lamp supplied from one transformer affected all the rest of the lamps, whether supplied from that transformer or

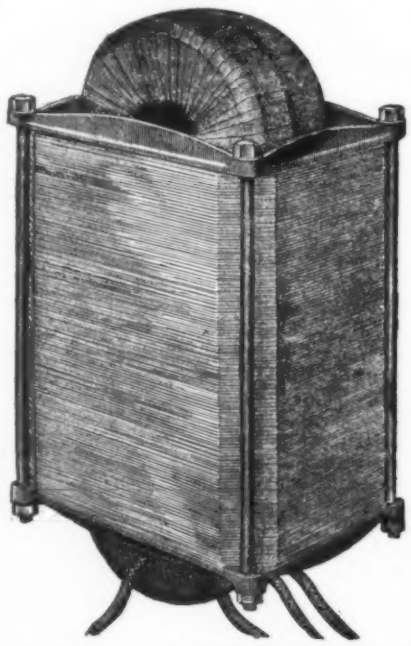


Fig. 77.—Early Pattern of Westinghouse Transformer Complete, but Without Box.

from any other; and with reduction in the number of lamps—when it was expected that the dynamo potential could be correspondingly reduced—an actual increase in voltage was found necessary. With the critical condition of exactly the same load on the same capacity transformers, the system made a splendid showing; but under ordinary conditions of variable loads, the interference of one customer's lamps with another, to say nothing of the expense of renewing ruined lamps, and the difficulty of attending to the dynamos, made the system a conspicuous failure. Certainly, it is easy to see that any effect produced on the primary circuit of one transformer, by varying the number of lamps, would equally be communicated through the series circuit to all the rest. The promoters made the mistake of supposing that by reducing the number of lamps on a secondary circuit, they would thereby allow the primary current to flow all the easier through the other winding. In this they missed the fundamental point of transformer action and regulation, for the very opposite of their beliefs was the truth. Primary and secondary windings are in such sympathetic relations that whatever contributes to resistance to the flow of current in one is equally felt by the other. The so-called lines of force produced by one winding so link themselves with the other that to all intents and purposes—except for the ratio of the number of turns—they might as well be the same winding.

Kennedy, in an article in the English Electrical

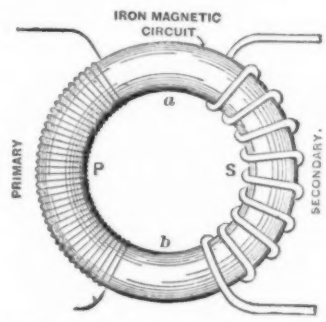


Fig. 78.—Typical "Core" Type Transformer.

Review, in 1883, showed that by connecting the primaries of the different transformers in parallel with each other, rather than in series, self-regulation would be possible. He had in mind, however, the existing experimental coils of Gaulard and Gibbs, with the same number of primary and secondary turns; and with such, the cost of conductors would exceed that for ordinary direct-feeding systems. To William Stanley, in 1885, seems due the credit for seeing just the solution of practical means for securing the benefits of high-tension transmission with low-tension supply for customers. The same high-voltage generator as tried with the series-connected transformers was proper; but each individual transformer, instead of being wound for low voltages only, should have its primary wound to withstand the full voltage, the various primaries should be connected in parallel with each other, and the generator, instead of being forced to supply a constant current, should merely act like a direct-current machine for incandescent lamps, i. e., supply all the current asked for, but always keeping the voltage fairly constant. Not being convinced of the practicability of this proposal, the Westinghouse Company would not try it; so Stanley was led to make the original proof at his own expense, and upon the practical proof of his surmises to organize his own company, in Pittsfield, Mass.

Once upon the right track, the applications of the transformer system of distribution were seen as almost unlimited. Gaulard and Gibbs sought to amend the specifications of their patent so as to embrace the parallel method of connecting, but failed; and the field was thrown open in this country and England to the free exploitation of alternating currents. In other European countries, however, Ganz & Co., of Buda-Pesth, Hungary, had been allowed some fundamental patents on similar systems, and through their unprogressive business methods and the lack of popular appreciation, rather small use was made, for a number of years, of the advantages of alternating currents. In England the development of supply systems met with some retardation by virtue of onerous regula-

tions as to the construction of the high-voltage mains imposed by the boards of trade; but in this country, permission to erect pole lines was usually not difficult to obtain, and electric lighting grew apace.

One of the first constructions adopted by the Westinghouse Company for its transformers was very effective, and even now hardly susceptible of improvement. Elongated coils of copper wire, with parallel sides and semicircular ends, were placed side by side,

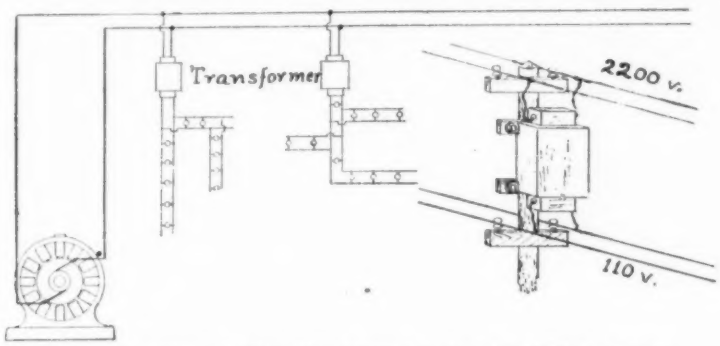


Fig. 79.—Transformer Alternating Current System for Multiple Circuits.

or one within the other, and formed the primary and secondary members. Each coil was insulated with cloth, paper, and mica, so as effectually to separate the two circuits. Thin sheets of annealed iron, punched in the form shown in Fig. 76, were then assembled on and over the coils and tightly clamped together by means of external bolts, until the complete structure appeared as shown in Fig. 77. The exact shape of the iron deserves special mention. There are cuts at f' and f^2; and to slip the sheets in place, the ends are temporarily bent over, as seen at f' and f^4. The central part, or tongue, as it is called, is then thrust through the open center of the coil, and the ends again bent down flat. The next sheet, instead of being passed through from the same side of coil, is put in from the other side, letting the cuts come at the side marked *A*. Then when the clamping is applied, each cut sheet is held between two at the outcut edges, therefore bringing the cuts as intimately together as if the metal was continuous. By making the magnetic circuit thus without sensible air gap, a very small amount of energy suffices to set up the necessary magnetic flux. The energy allowable for providing this magnetism must be of the smallest amount possible, for the primary coil is permanently connected to the mains from the generator; and whatever loss from this source is tolerated must be continued twenty-four hours a day, although the lamps may be used but a few hours during that time. Some transformers have been made with their clamping bolts passing through holes in the sheets, but this construction is faulty, and is not now tolerated. The reason is that though insulated from the rest of the iron, they lie directly in the path of the lines of force, and suffer the generation of wasteful and heating eddy currents. Even if the bolts are made of some non-magnetic material, their presence introduces an unnecessary narrowing of the section of the iron for the magnetism. In Fig. 77, the bolts are seen to lie quite outside the field. For out-of-door use, the structure is of course placed in an iron

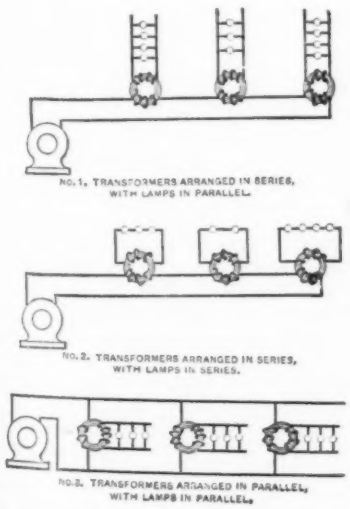

NO. 1. TRANSFORMERS ARRANGED IN SERIES, WITH LAMPS IN PARALLEL.
NO. 2. TRANSFORMERS ARRANGED IN SERIES, WITH LAMPS IN SERIES.
NO. 3. TRANSFORMERS ARRANGED IN PARALLEL, WITH LAMPS IN PARALLEL.

Fig. 80.—Comparison of Three Methods of Arranging Transformer Systems.

box, sometimes provided with ventilating spaces at the bottom, but securely closed from entrance of water at the top. The box itself is sometimes made to do the clamping of the sheets, the coils themselves being depended upon to hold the iron until transference, or the sheets prevented from slipping on each other by means of wooden pins through holes punched in the corners. In order to provide room for the holes, the corners of sheets are left square, instead of being clipped, as shown in these figures.

With the coils thus nearly concealed from view or inclosed by the sheet iron, the construction is technically designated as the "shell" type, as if the electrical part was placed in a shell. One defect of this arrangement is found in the fact that the coils do not have a very good opportunity to radiate their heat. Another construction has been developed and approved by some of the largest users. This is known as the "core" type, and its principle can be seen from the elementary diagram given in Fig. 78. In this a ring is supposed to be wound of annealed iron wire, and on opposite sides of this the fine and coarse copper wire coils, respectively, are placed. Every time the primary current reverses, the direction of the resulting magnetism changes, and as the flux passes around

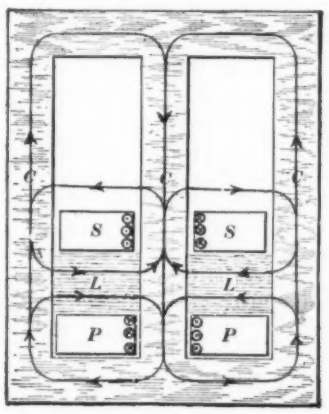


Fig. 81.—Magnetic Circuits of Constant Current Transformer.

the complete circuit of the ring, there is induced in the secondary winding an alternating electromotive force. In this diagram the fine wire is designated as the primary, and this conception is usually in accordance with the ordinary uses of transformers for distributing electric energy to customers; however, for very long-distance transmission, it is common to employ step-up transformers, and in such cases the coarse wire would properly be called the primary. This case is seen to agree with the phraseology regarding induction coils, in which a meager battery voltage is exchanged for an alternating one of considerably high value. That is always the primary which is connected to the source of energy. Identical transformers could be used, one connected to a generator, for raising the voltage and delivering the energy to the line, the other receiving the energy and lowering the voltage to a suitable value for distribution. In one the coarse winding would be regarded as the primary, in the other as the secondary.

Cores of the ring form have actually been made; but like an ordinary ring armature for a dynamo, they are tedious and expensive to wind, and the same results can be obtained in a better way by having the iron sheets in the shape of a U, with square corners, the straight sides being of two lengths. The coils can be wound in a lathe, or its equivalent, slipped onto these ends, and the magnetic circuit then completed by alternate long and short cross strips of sheet iron. This modification of the core type presents good opportunities for insulating the coils, even in small sizes, exposes a large surface for radiating the heat, and is rather more easily repaired than the shell type. For improving the regulation, primary and secondary winding are equally disposed on both limbs.

For outdoor use, on poles, or on the walls of houses, there is a fairly good chance for preventing excessive rise in temperature; but even a small amount of heat continued indefinitely dries the insulation to crispness, and often reduces its strength. A practice now very common is to fill the transformer boxes with paraffin oil; this in itself is a good insulator, and further it keeps the other insulations in a flexible condition, serves as a carrier of the heat, generated in the coils, to the outer walls, and in case of a puncture of the insulation between the windings, often due to lightning, the oil extinguishes the arc and seals the hole. For indoor use, large transformers are usually made of the shell type, with numerous air ducts, through which lively currents of outdoor air are driven by means of a blower. Still others are immersed in oil in tanks of boiler iron, and the oil continually cooled by circulation of cold water through a series of iron pipes suspended in the upper part of the tank. Of course this expenditure of energy in cooling the coils should be taken into account in estimating the working efficiency of an installation; but really, the percentage of total energy is very small, the practical point being that if one per cent of the total be thus expended, considerably smaller transformers may be able to carry the load. The case is not essentially different from that of a dynamo, in that considerable dependence is placed upon the fanning action of the revolving member to keep the coils from getting too hot. The transformer, having no revolving part, may as well have this circulation supplied by some exterior device.

Common primary potentials for distribution circuits are 2,000 to 2,300 volts, and the secondary coils have one-twentieth as many turns as the other. A customer will then be supplied at 100 or 115 volts, closely imitating the direct-current service. Formerly, it was regular practice to give each customer a separate transformer, and this was usually located on the wall of the house. This practice introduced an unnecessary fire risk, and the monotonous hum produced by the vibrations of the iron sheets as they experienced the alternating magnetism often communicated a disagreeable noise throughout the whole house. These conditions are removed and greater economy in first cost as well as in operating expenses is attained by using a lesser number of transformers, though of somewhat larger size, but mounted on the poles, or at convenient centers, and with their secondaries connected to mains of their own. Customers are supplied from these latter. A representation of such an arrangement is given in Fig. 79. In this, the parallel rather than the series method of connecting the primaries is clearly brought out. In case of reasonably large loads, or considerable distance between different houses, the secondary circuits would usually be of the three-wire variety, giving double voltage between outer wires. Such an arrangement can be obtained from most transformers, for the secondaries are usually formed of two coils that for some service can be connected in parallel, but for other service in series, and a tap for the neutral led out from this junction. Another method for furnishing a three-wire system is to use two identical transformers, their primaries being connected in parallel, as usual, but their secondaries in series, with the neutral led from this junction. The primaries, too, of standard transformers are often composed of two separately insulated coils that can be put in parallel for use on 1,000-volt circuits, or in series for those of 2,000 volts.

Although the parallel method of connecting transformers has now entirely supplanted the other, yet somewhat to recuperate itself for its early expendi-

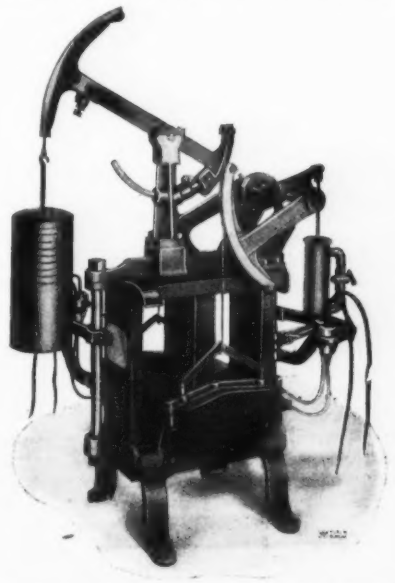


Fig. 82.—Small Size Constant Current Transformer (Air-Cooled). Complete, but with Case Removed.

tures, the Westinghouse Company once manufactured and advocated a series system for arc lamps that was fairly operative, the faults being largely confined to the impossibility of making good working lamps. Such a system is a consistent one, for if the primaries were in series, the secondaries had their load also of series-connected lamps. When the generator is made to supply a constant current, as would be the case with

a direct-current dynamo, these secondary circuits, too, would supply a fairly constant current. To turn a lamp off, it should simply be short-circuited, exactly like one of the direct-current sort; and when the last in a given circuit was turned off the secondary of transformer would thereby be on a complete short-circuit. This would mean no harm, however; for with the primary current kept at a limited constant value, the secondary would be powerless to do differently. Through such a short-circuited secondary the current could flow with the least expenditure of electromotive force, and relieve the dynamo of that proportionate load. This, it is recognized, is the very object aimed at by Gaulard and Gibbs; but they made the mistake of mixing series and parallel methods of distribution. With the primaries of the transformers in series, the various elements of the loads must also be in series, while for parallel operation of these loads the primaries must likewise be parallel. Just as in the case with direct-current apparatus, if the lamps are to be in series, the dynamo must be series wound; while for incandescent lamps or motors in parallel, the field must have its independent, or shunt, winding. In other words, the generating and utilizing parts of the apparatus must have a certain harmony or consistency of arrangement.

The comparison of three possible arrangements of transformer systems is well brought out in Fig. 80. For clearness, ring transformers, resembling the one shown in Fig. 78, are shown. No. 1 represents what Gaulard and Gibbs and the Westinghouse Company first tried, but for other than particular and critical loads found inoperative; No. 2 is actually practical, and was exploited by the Westinghouse Company until better means for accomplishing the same results were devised; No. 3 shows the ordinary and remarkably satisfactory arrangement.

To operate several hundred, or even several thousand, arc lamps for street lighting, all from a single generator, has been the aim of many an engineer. For economy of wiring it is certain that as many lamps as possible should be placed in series, yet the possibilities of large generators quite clearly lie in those of the constant-potential order. The problem then was to operate series circuits, each with its control for constant current, in parallel with each other from a constant-potential source. The conditions involved are just the reverse of the Gaulard and Gibbs proposal; but without special transformers the operation is just as impracticable.

The theory of the proper construction of the latter shows that there must be a large leakage path for the lines of force; that is, when diminished electromotive force is desired of the secondary, more of the lines of force produced by the primary shall not cut through the former, but find opportunity to pass across a purposely-prepared magnetic sort of shunt. By taking this alternative path, the primary will act more like a choking coil, and consequently draw less current from the generator—just the end sought. Reverse conditions will give the opposite results. For years it was sought to embody such a transformer in an entirely stationary structure, but the outcome was discouraging. The efficiency was low and the regulation bad. Then Elihu Thomson, with the vision before him of the shifting brushes of his arm dynamo, and the coincident complexities of the magnetic circuit, resolved to imitate those conditions in a transformer. A long magnetic circuit was provided, with large opportunity for leakage between opposing flanks. Thin flat primary coils were at top and bottom, with similarly shaped secondary coils movable between them. Since, in the two sets of coils, currents flow in opposite directions, a repulsion will exist between them, and by suitably counterbalancing, the secondary current may be adjusted to any desired value. Some of the small sizes of this style of transformer are made with single primary and secondary coils, and in Fig. 81 is seen a representation of the arrangement of the parts. The directions of the currents and various paths for the lines of force at some one instant are suggested. The region between the coils is permeated with numerous leakage lines, and for a greater or less secondary current, the upper coil moves into a closer or more remote part of this field. This variable position of the secondary coil is equivalent to driving the armature of a dynamo at variable speeds, therefore just enough electromotive force is generated always to keep the secondary current at the same value. A view of the complete transformer is given in Fig. 82. In practice, the large sizes are placed in a tank of paraffin oil, whereby, in addition to the gain in the insulating qualities, some retardation is offered to sudden movements of the secondary. In this respect a close imitation of the function of the dash-pot of the direct-current dynamo is made. In those dependent upon air-cooling, the dash-pot is actually used, as seen at the right in Fig. 82.

The constant-current transformers are thus seen to be devices not appropriate for mounting on a pole, but need to be kept under supervision in a station. In addition, they are not as cheap as it was once hoped to make them; but their finely working qualities have made them very popular. With no revolving part, and requiring small floor space, they occupy even in connection with the constant-potential generator for supplying the primary current, not more than one-tenth the space demanded for the former direct constant-current dynamos of the familiar Brush or Thomson-Houston style. Of course, the arc lamps receive alternating currents; but where such are not allowable, the constant-current transformers can operate in connection with the modern device known as the mercury arc rectifier, and deliver to the exterior circuit a direct current.

The eighteenth chapter will consider devices that may be called "current reorganizers."

THE EDISON CONCRETE HOUSE.*

THE PRACTICAL PROBLEMS INVOLVED.

BY PERCY H. WILSON, ASSOC. M. AM. SOC. C. E.

IN describing Mr. Edison's idea the writer proposes to confine his discussion of the subject to practical engineering and the structural difficulties encountered.

In order to effect the greatest saving in cost, speed in the actual work of construction, and the designing of a set of forms built of such a material that could be used many times, with little wear and little or no repair, the use of metal was decided upon. The using of metal for forms is not a new idea, although the practice has been limited very generally to concrete chimneys. The concrete chimney forms were of boiler iron, braced with ells, and were easily put out of shape, and were unsatisfactory in other ways. The use of milled castings for forms overcomes the above objections, and furnishes almost an ideal form from the point of wear and repair. Their rigidity, a point of absolute necessity in concrete construction work, depends only upon the thickness of the casting.

The placing of all the concrete at once, was naturally a result to be obtained, if possible. The theory of placing concrete in layers of six inches, or a foot, has long since been considered unnecessary, but never before has the possibility of placing the concrete in an entire house, in a single day, been contemplated.

Originally Mr. Edison says his idea was to treat the house as a casting made of concrete. In making good castings, the molds must be perfect, the material from which the casting is made must be brought to perfect fluid state, and adequate arrangements must be made to get rid of the air.

The use of cast iron forms solved the question of mold. The next question was to bring the mixture of water, cement, sand, and stone to as nearly a perfect fluid state as is possible. In order to accomplish this a colloid was used, namely, clay. Mr. Edison's experiments lead one to believe that the use of this colloid will at least insure the running of the mixture to all parts of the forms, and there will be no voids. The ejection of the air could be accomplished in several ways, but the giving to the floor a slight camber, with a blow hole at the highest point, seems to be the most feasible. With the mass flowing into every part of the forms, due to the use of the colloid, the next question is, will the mass disintegrate, due to the obstruction to free flow presented by the reinforcement and the necessary plumbing and heating pipes and to the action of gravity?

The restriction of flow due to the reinforcing, etc., will be more serious the larger the size of the stone used. If ¼-inch were used, there would probably be no appreciable resistance. No doubt where the reinforcing crosses, or is spliced, the larger stones will collect, one stone being added at a time, but this will be very much like floating sheet ice in a river, held by a group of piles. The first piece sticks, then another and another, until finally so much is added to the stationary pile that the whole is caught by the passing current or the floating ice, and is swept away.

The settling of the larger and heavier particles in the concrete to the bottom, due to the action of gravity, depends more upon the disturbance of the mass after it is in place and also the speed with which the concrete gets its initial set, than upon the action of gravity alone. There will be no settling of stone to the bottom of the forms after the cement has taken its initial set. And the important point to determine is, as to how the mass of concrete flows into the floor forms. Concrete certainly has an angle of repose and the question is what this will be. Will the concrete, upon being placed, spread in a thin layer, say one inch thick, over the whole area of floor forms? If so, there will surely be a settling of the larger particles to the bottom of the floor. Or will it fill the forms from top to bottom, and be gradually worked from the sides by the pressure of the head of concrete in the side walls assuming an angle of repose of say 30 degrees? This would seem to depend upon the amount of water used and Mr. Edison emphasized the fact that just the proper quantity of water must be used. In experimenting, a box with one glass side would seem to afford one an opportunity of observing the physical action of the concrete while being placed. In a sea wall at Annapolis the writer's firm placed concrete in water to a depth of five feet, it being placed by starting at one end of the forms and working longitudinally along the wall toward the other end. The concrete was mixed wet, and in placing, was brought to the elevation of the surface of the water, in the meantime being allowed to assume a natural angle of repose in the forms. In spite of the fact that an immense excess of water was used, the concrete assumed an angle of repose of about 30 deg., and no difficulty was experienced on account of stones separating from the mass and rolling down the slope to the bottom of the form. The wall was afterward examined by a diver, and no disintegration of material could be observed. A 1-3-5 mixture was used with run of crusher stone 2 inches and under.

That the addition of clay, the necessary colloid, weakens the concrete, seems to be the disputed question. Tests made some time ago would seem to show that by the addition of a small amount, the strength of the concrete is not affected. Its addition will, however, slow up its setting but at worst will only postpone the time of the removal of the forms. Mr. Edison's latest experiment, which is being tried at the present time, contemplates putting the concrete through a vertical 4-inch box 10 feet long, and then through a horizontal box about 5 feet long up through a vertical box 5 feet long, then another horizontal reach of 5 feet, then through a vertical drop of 5 feet, and then another horizontal reach of from 3 to 5 feet, and finally up a vertical reach as far as the cement will flow. Of course, the head in the original vertical reach has something to do with the distance through which the concrete can be forced, but if the experiment is successful engineers will be convinced that Mr. Edison has at least discovered a way to make concrete an almost perfect fluid.

Briefly referring to the plant necessary, every contractor would have ideas of his own as to the amount of plant and the exact way in which the same should be utilized, experience very largely directing to the contractor which particular class of plant could be most economically operated by him. It would seem that a practical man would probably reduce rather than increase the amount of plant suggested by Mr. Edison. This of course would lessen the cost of the house as regards the item of interest on the investment and depreciation of the plant.

To give a brief *résumé*, Mr. Edison seems to have conclusively proved, (1) that a house can be built in the way he states; (2) that every practical construction problem involved can be solved; (3) that a mixture of concrete can be obtained which will insure its flowing to all parts of the forms, thus avoiding voids.

His experiments have not gone far enough as yet to definitely determine the following:

First: Does the addition of the necessary colloid delay the setting of the concrete, or affect its strength?

Second: Will the stone separate from the sand and cement and form a non-uniform mass either in placing, or at a later period, due to the action of the laws of gravity?

The first of these items very naturally affects only

* Reprinted from the Cement Age.

the cost of the building. The second affects its stability and must be solved definitely before the building of a house in this way can be accomplished.

On the whole the idea is one of rather revolutionary type in engineering construction, but judging from what Mr. Edison has already accomplished toward the solving of the practical difficulties which have arisen, it is likely that he will in the end be successful in building a house in the way he has planned.

THE EYE OF MATHEMATICS.*

WHAT THE TRAINED IMAGINATION CAN DO.

BY PROF. CASSIUS J. KEYSER.

OBSERVATION by the inner eye of the things of thought is observation, not less genuine, not less difficult, not less rich in its objects and disciplinary value, than is sensuous observation of the things of sense. But this is not all, nor nearly all. Indeed for direct beholding, for immediate discerning, of the things of mathematics there is none other light but one, namely, psychic illumination, but mediately and indirectly they are often revealed or at all events hinted by their sensuous counterparts, by indications within the radiance of day, and it is a great mistake to suppose that the mathetic spirit elects as its agents those who, having eyes, yet see not the things that disclose themselves in solar light. To facilitate eyeless observation of his sense-transcending world, the mathematician invokes the aid of physical diagrams and physical symbols in endless variety and combination; the logos is thus drawn into a kind of diagrammatic and symbolical incarnation, gets itself externalized, made flesh, so to speak; and it is by attentive physical observation of this embodiment, by scrutinizing the physical frame and make-up of his diagrams, equations and formulæ, by experimental substitutions in, and transformations of, them, by noting what emerges as essential and what as accidental, the things that vanish and those that do not, the things that vary and the things that abide unchanged, as the transformations proceed and trains of algebraic evolution unfold themselves to view—it is thus, by the laboratory method, by trial and by watching, that often the mathematician gains his best insight into the constitution of the invisible world thus depicted by visible symbols. Indeed the importance to the mathematician of such sensuous observation cannot be overrated. It is not merely that the craving to see has led to the construction of the manifold models, ingenious and noble, of Schilling and others, illustrating important parts of Higher Geometry, Analysis Situs, Function Theory, and other doctrines, but the annals of the science are illustrious with achievements made possible by facts first noted by the physical eye. To take a simple example from ancient days, it was by observation of the fact that the square of certain numbers are each the sum of two other squares, the detection and collection of these numbers by the method of trial, observation of the fact that apparently all and only the numbers of such triplets are measures of the sides of right triangles—it was thus, by observation and experiment, by the method of incomplete induction, common to the experimental sciences, that the Pythagorean theorem, now familiar throughout the world, was discovered. It was by Leibnitz's observation of the definitely lawful manner in which the coefficients of a system of equations enter their solution that the suggestion came of a notion on the basis of which there has grown up in our time an imposing theory, an algebra built up on algebra—the colossal doctrine of Determinants. It was the observation, the detection by the eye of Lagrange and Boole and Eisenstein, of the fact that linear transformation of certain algebraic expressions leaves certain functions of their coefficients absolutely undisturbed in form, unaltered in frame of constitution, that gave rise to the concept, and therewith to the morphological doctrine, of Invariants, a theory filling the heavens like a light-bearing ether, penetrating all the branches of geometry and analysis, revealing everywhere abiding configurations in the midst of change, everywhere disclosing the eternal reign of the law of form. It was in order to render evident to sensuous observation and to keep constantly before the physical eye the pervasive symmetry of mathematical thought that Hesse in the employment of homogeneous co-ordinates set the example, since then generally followed, of replacing a variety of different letters by repetitions of a single one distinguished by indices or subscripts—a practice yet further justified on grounds both of physical and of intellectual economy. It was by sensuous observation that Clerk Maxwell, in the beginning of his wondrous career, detected a lack of symmetry in the then recognized equations of electrodynamics, and by that observed fact together with a discriminating sense of the scientific significance of esthetic intimations, he was led to remove the seeming blemish by the addition of a term, antedating experimental justification of his daring deed by twenty years; an example of prescience not surpassed by that of Adams and Leverrier who, while engaged in the study of planetary disturbance, each of them about the same time and independently of the other, felt the then unknown Neptune "trembling on the delicate thread of their analysis" and correctly informed the astronomer where to point his telescope in order to behold the planet. One might go on to cite the theorem of Sturm in Equation Theory, the "Diophantine Theorems of Fermat" in the Theory of Numbers, the Jacobian "doctrine of double periodicity" in Function Theory, Legendre's law of reciprocity, Sylvester's reduction of Euler's problem of the Virgins to the form of a question in Simple Partitions, and so on and on, thus continuing indefinitely the story of the great rôle of observation, experiment and incomplete induction, in mathematical discovery. Indeed it is no wonder that even Gauss, *facile princeps mathematicorum*, even though he dwelt aloft in the privacy of a genius above the needs and ways of other minds, yet pronounced mathematics "a science of the eye."

Indeed the time is at hand when at least the academic mind should discharge its traditional fallacies regarding the nature of mathematics and thus in a measure promote the emancipation of criticism from inherited delusions respecting the kind of activity in which the life of the science consists. Mathematics is no more the art of reckoning and computation than architecture is the art of making bricks or hewing wood, no more than painting is the art of mixing colors on a palette, no more than the science of geology is the art of breaking rocks, or the science of anatomy the art of butchering.

Did not Babbage or somebody invent an adding machine? And does it not follow, say Holmes and Schopenhauer, that mathematical thought is merely a mechanical process? Strange how such trash is occasionally found in the critical offering of thoughtful men and thus acquires circulation as golden coin of wisdom. It would not be sillier to argue that, because Stanley Jevons constructed a machine for producing certain forms of logical inference, therefore all thought, even that of a philosopher like Schopenhauer or that of a poet like Holmes, is merely a thing of pulleys and levers and screws, or that the pianola serves to prove that a symphony by Beethoven or a drama by Wagner is reducible to a trick of mechanics.

So Nature causes considerable expenditure for man. She herself is a spendthrift, as in a storm she wastes giant forces. The storm that destroyed Galveston could have furnished the power given by all the steam engines of the world for years. A single thunderstorm would suffice to drive all the dynamos in existence, and the average value of a flash of lightning has been calculated as about $1,250.

* Abstract from a lecture on mathematics, delivered at Columbia University, in the series on Science, Philosophy and Art.

LOSSES RESULTING FROM BAD WEATHER.

OF course every one is interested in the weather, but few think how much effect it has on trade. In this connection the Dresdner Anzeiger sums up, apparently from English sources, some figures concerning the cost of bad weather to those engaged in the different branches of trade. When it rains, nearly all tradesmen complain of bad business, except the cigar dealers; the latter, however, rub their hands with delight. The desire to make a bad day more endurable by a good cigar increases the takings of the cigar dealer by 15 per cent. That public-house keepers in the city have no cause for complaint, every one knows. Whoever has anything to do in the street supplies himself with umbrella and rain coat, and these cost money. In nearly all other shops the proprietors wait unavailingly for customers. Ladies especially have no great desire to shop in the rain. That means a considerable loss of trade; it has been estimated that the shops in the West End of London lose by a single rainy day $500,000.

Some kinds of merchandise are especially sensitive to the influence of the weather. Mutton and pork, for instance, are spoiled by very strong electric discharges; so that many a butcher will lose $50 to $75 by a thunderstorm.

A real London fog is much more expensive, by reason of its impenetrable darkness. For gas alone, London expends per day, when there is a fog, $7,500 more than usual. The apothecaries are pleased by such weather, for the reason that it causes a number of diseases, so that their income is doubled. The underground railways also have their income increased by rain and fog. Naturally, it is much more pleasant to be protected from wind and wet than to sit on top of an omnibus and get soaked through.

OZONE IN A GERMAN THEATER.

THOUGH the sterilizing effects of ozone have been known for some time, no successful attempts seem to have been so far made to utilize these effects on a practical scale, especially for the purifying of the air.

Ventilators will supply to crowded rooms continual amounts of more or less pure outside air; but this air usually requires heating, which greatly increases the cost of operation. These drawbacks are obviated by using ozone to produce a pure atmosphere without any draft or change in temperature. Interesting experiments on this use of ozone have been made in the course of the past year at the Royal Theater, Stuttgart, the vestibule, foyers, cloakrooms, and supers' hall being aerated effectively with an ozone apparatus. The success of these experiments, made on a small scale, led to a full installation of pipes connected to the ozone apparatus being carried to each point in the theater where ozone was needed. The supply was accurately controlled, and the whole auditorium supplied in a few minutes with sufficient ozone to destroy any traces of bad air throughout the building.

The cost of operation of this process was found to be extremely low, while any draft or increase in temperature was done away with. Similar success has attended experiments recently made in telephone exchanges, hotels, cellars, and assembly halls.

The apparatus, according to a recent issue of the Gesundheitsingenieur, comprises a small electromotor actuating an air blower, while another motor is converting continuous current into alternating current, to which the tension required for adequate working is imparted by a transformer. The alternating current enters the ozone battery, where it traverses the field of electric discharge. The air coming from the blower being thrown through the field of discharge undergoes the conversion of its oxygen into ozone. This apparatus should contribute to a solution of the ventilating problem, and would seem to be a new departure from the hygienic point of view.

BRAZILIAN COPAL GUM.

FOR the benefit of American inquirers who are interested in "jatoba" or "jatahy," commonly known as Brazilian copal gum, Consul-General George E. Anderson, writing from Rio de Janeiro, says that it seems safe to say that considerable business in this product can be done if there is sufficient demand for it to warrant gathering it on a large scale. He adds:

"Last year the exports of the product from Brazil amounted, at a valuation of about 67 cents a pound, to a total of about $9,000. The quality of the gum, as suitable for use in the manufacture of varnish and for some medicinal purposes, is said to be very good. There are large supplies of the product to be had in Minas Geraes in pockets in the ground, being thus collected by the burning of forests containing trees bearing the gum. The gum being thus melted forms pools, which harden and preserve the product. The trade in the gum so far has been so small that there has been no systematic effort to work these sources of supply.

The increase in suburban railway traffic at Rio de Janeiro has been so great as to call for some solution of the problem of providing adequate facilities for the large population which depends for transportation upon these trains. The number of passengers carried in the suburban trains increased from 12,600,000 in 1901 to 19,250,000 in 1906, an increase of about 52 per cent. It has been proposed that the suburban lines be electrified, and plans are now being made to that end. The mileage will probably be about 20 miles. The plan specifies that trains are to run on a schedule providing a three-minute service, or twenty trains per hour, accommodating 40,000,000 passengers per year.

THE COLBURN WINDOW-GLASS MACHINE.

THE FIRST MACHINE FOR DRAWING WINDOW GLASS CONTINUOUSLY IN ANY WIDTH.

MOST of the world's window glass is made by what is known as the cylinder process. Originally the cylinder process was a handicraft; latterly machinery has been introduced to take the place of the workman's lungs. Despite the introduction of mechanical methods of forming the cylinders, one-half of the American supply of window glass is still made in the old way. For this reason a brief description of the cylinder process is necessary, all the more so since the wonderful advance marked by the machine to be presently described cannot be otherwise fully grasped by one unfamiliar with the glass making art.

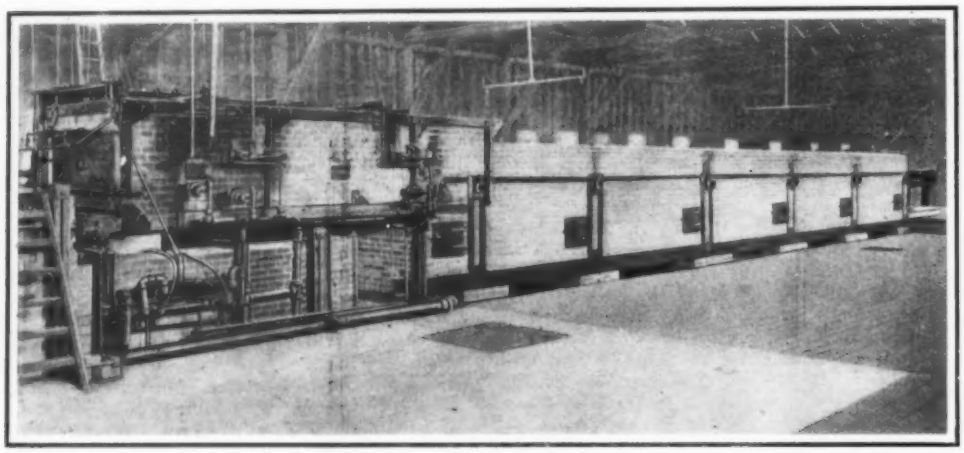


FIG. 5.—RIGHT-HAND SIDE OF WORKING CHAMBER, DRAWING MACHINE, LEHR, AND CUTTING TABLE.

In the cylinder process, then, a workman known as a "gatherer" collects a ball of plastic glass on the end of a blowpipe. From the gatherers the balls pass to workmen called "blowers" and "snappers," whose duty it is to block and shape the mass. By the sheer force of his lungs the blower inflates and shapes the glass until it forms a sphere of some size, and then elongates the bubble while swinging it in a swing hole. This partially completed cylinder is reheated and by repeated blowing and swinging is finally given its proper shape and length. The lower end of the cylinder is then warmed and blown open. Thus a ball of glass is inflated to a cylinder, which is usually from four to eight feet in length, according to the desired dimensions of the finished sheet. After the cylinder has been cracked from the blowpipe, and the neck severed from the cylinder with a thread of red-hot glass, the work of flattening begins. First the cylinder is cracked lengthwise with a red-hot iron and placed in an oven where it is heated, flattened, and annealed.

Apart from the fact that the output of cylinder glass is necessarily restricted by reason of the skilled labor employed and the limitation of human endurance, the process is far from certain. The gatherer is obliged to make numerous gatherings before he secures a plastic ball of sufficient size, with the result that air is often imprisoned in the mass and is eventually blown out in long blisters. The blowers and snappers sometimes leave block-marks in the glass. Finally, the flattener, into whose hands the cylinder passes after having been capped off and cracked open, often ruins more glass than the gatherer, snapper, and blower combined; for in laying open the cylinder with his long iron rod, he may mark the glass, and in laying the glass down on the flattening stone and rubbing it down to a flat surface, he may mar the surface, besides running the risk of having the glass adhere to the stone.

The machine cylinder process overcomes in a measure the difficulties encountered in the earlier stages of the hand process. The glass is ladled from the furnace to a drawing pot, during which ladling, air is frequently impounded, which manifests itself in the sheet in the form of blisters. Sometimes striæ or strings are produced by the rough interior edge of the clay drawing-pot. In operating the blowing machine considerable skill must be exercised for the production of uniform glass and for the regulation of the air blast by which the cylinder is dilated. After the cylinder is blown, the glass is treated by hand exactly in the manner previously described, with all the attendant risk of injury.

In any effort to make flat window glass by mechanical means only, the idea of passing the plastic glass through hot rolls immediately suggests itself. It has been found, however, that, while it is possible to obtain sheets of the desired width and thickness, the glass is not marketable because it is chilled on coming in contact with even the most fervid rollers. Instead of exhibiting the limpid transparency and high-fire polish so much desired, the glass is almost frosted in appearance, because of the infinitesimal surface cracks. To grind such a sheet to transparency is too expensive.

Another obvious method of overcoming the difficulty is to drive the molten glass through a slit of the proper length and width. Here again the difficulty of obtaining perfectly transparent glass is encountered. As soon as the glass touches the fire clay of the slit, its surface is scratched.

Any attempt to draw sheet glass from a melting pot is met with the supreme obstacle of controlling the width of the sheet as it is pulled. Like all viscous substances molten glass tends to narrow down to a thread as it is elongated. To maintain the width by gripping the edge of the glass with clamps as it emerges from the pot is impracticable.

By far the most systematic and painstaking study which has been made of the whole problem, we owe to Mr. Irving W. Colburn, of Franklin, Pa. He has attacked it from every conceivable side, expended large sums in experimenting, built and destroyed machine after machine, and after ten years has at last built the first commercially successful apparatus for drawing sheet glass of any reasonable width and of any desired thickness, surface, and polish. At the Franklin plant there are no gatherers, blowers, snappers, or flatteners. The cutters and the superintendent are the only skilled men employed, and the cutters will some day give way to automatic devices. With three men and six boys more glass and better glass is made by the machine than can be made by thirty-nine men with the cylinder process. At present the plant is running twenty-four hours a day, three shifts of eight hours each. The six cutters employed cannot keep pace with the output, for which reason more cutting tables are being installed.

The essential novelty of Mr. Colburn's machine is to be found in the devices for drawing a sheet of uniform width from the melting pot. The devices in question are illustrated in Fig. 10. Spheres of fire-clay, carried on the ends of long arms, are plunged in the molten glass and revolved upwardly and outwardly, and away from the edges of the sheet. These spheres impart an outward motion to that portion of the molten mass lying adjacent to the edges of the sheet, thereby counteracting that tendency to shrink and draw to a thread which has ever constituted the supreme obstacle in designing an efficient machine. By this means sheet glass of any desired width and of a thickness varying at the will of the operator from 1-16 to ¼ of an inch could be drawn continuously. Ribs or wave-like lines or striæ, however, were formed upon the surface of the finished product. These were very minute, but still perceptible enough to distort the visual rays. After observations and experiments extending over a year, it was discovered that the defect was due to several causes, among which was the tendency of the glass to receive on its surface impressions from the rough side walls of the pot, particularly if the point at which the glass left the walls was only a few inches from the point at which the glass entered the sheet. Moreover, the chilling influence of the atmosphere on the surface of the glass, while molten in the working chamber, caused it to lie dormant in spots and also to wrinkle slightly. These defects were hardly perceptible to the eye, but existed nevertheless, and caused the disastrous wave lines when the glass entered the sheet form. Dust particles dropping into the working chamber were also a source of serious trouble. It seems that such particles, however minute, adhering to the surface of the molten mass, are gradually incorporated in the sheet, and the blemish made by them is elongated so as to produce a wave, line, or cord. Mr. Colburn found that by placing near and on each side of the sheet a rotating fireclay cylinder, slightly immersed in the molten mass (Figs. 11 and 12), and at the same time superheating remote portions of the glass, the difficulties were overcome. These rollers are rotated in opposite directions during the operation of drawing the sheet of glass, and serve not only to impart movement to a portion of the surface of the molten mass away from the faces of the sheet during the drawing operation, but also to determine the area of the surface in the working chamber or pot, which is more or less exposed to the cooling influence of the atmosphere, the superheating occurring on that portion of the surface of the molten mass to the rear of the rollers. These rollers make but one revolution in from ten to thirty minutes, depending upon existing conditions, and serve also as a most perfect equalizer of temperature of the molten glass in the working chamber, which is an absolutely necessary factor in drawing an even thickness of sheet glass. A film of plastic

FIG. 6.—RIGHT-HAND SIDE OF DOG HOUSE, WORKING CHAMBER, AND DRAWING MACHINE. THE SHEET OF GLASS CAN BE PLAINLY SEEN.

FIG. 7.—LEFT-HAND SIDE OF DOG HOUSE, WORKING CHAMBER, AND DRAWING MACHINE. THE SHEET OF GLASS CAN BE PLAINLY SEEN.

glass adheres to the rollers and is carried upward and over them, chilling slightly in the chamber *A*, because of the presence of the water jackets *C C*, which are inserted, one on each side of the emerging sheet of glass. These jackets are not designed to chill or thicken the sheet, but merely to screen off the heat radiating from the revolving white-hot clay rolls. The plastic film of glass on the roller melts off entirely in the superheating chambers *B B*.

As the sheet of glass is drawn from the mass of glass lying between the rollers, and as the spheres impart an outward movement to that portion of the surface of the mass lying immediately adjacent to the edges of the sheet, the following effects are observed: The molten glass at and just beneath the surface adjacent to the edges of the sheet moves outwardly and away from the central line of the sheet, thus serving to hold the sheet to its full width. As the sheet moves upward there is drawn into it some of the surface portion of the molten mass immediately adjacent to its two faces, and also some of the molten glass beneath the surface. The skin or surface portion of the glass in the working chamber adjacent to the sides of the sheet being drawn, becomes the skin or surface of the finished drawn sheet. Simultaneously the two rollers on opposite sides of the sheet of glass skim some of the surface portion of the molten glass lying between the rollers and the sheet of glass away from the sheet. The result of the combined action of the drawing of the sheet and the movement of the rollers is a constant skimming of the molten glass lying between the two rollers, so that a fresh portion or a new surface is constantly being exposed to the cooling effect of the atmosphere, which has not time to form wave lines on its surface before it has passed into the drawn sheet or over the revolving rollers. Furthermore, the rollers serve to bring a supply of fresh and uniformly heated molten glass into the area lying between the rollers and the sheet. The glass which is skimmed from the surface by the rollers and carried over them is subjected to the superheating action in the chambers *B B*, as already explained, and is melted down so as to free the rollers from the adhering film, and restore the film itself to a proper working condition. Simple as the expedient of the rollers may seem, it meant months of painstaking observation and experimenting before they were conceived..

After the sheet is started, it is drawn upwardly from the melting pot and passed over a bending-roll *A* (Fig. 8), fixed to a water-cooled shaft, rotating in water-cooled ball-bearings, the glass being sufficiently heated to bending plasticity by the gas-burners *B*. The sheet then glides on a horizontal carrying table *C*, which consists essentially of two parallel chains which are connected by slats constituting the table proper and which are driven by sprockets D^1 and D^2. In order that the sheet may be pulled along through the chamber *E*, sprocket chains *F* are mounted above the carrying-table, from which chains grip-bars *G* depend to engage the sheet at intervals of five feet.

It is evident that the speed at which the carrying-table travels must be nicely adjusted to the speed at which the sheet is formed in the pot. If the speed of the carrying table is much greater or less than the speed of sheet-formation, it would be impossible to obtain a sheet of uniform thickness. Accordingly, we find that the inventor has operatively connected the rollers in the pot, the revolving spheres, the sprockets D^1 and D^2 of the carrying-table and the sprocket chains *F*, so that all are driven from a common power shaft by suitable gearing. The relative speed of each moving part is therefore preserved. While the sheet is passing over the roll *A*, the carrying-table is exerting a pull of about eight pounds to each foot in width, which pull, together with the weight of the glass in the opposite side of the bending roll, is sufficient to flatten the glass perfectly.

From the carrying table *C*, the sheet glides upon a second carrying table *C'*, which is a duplicate of the carrying table *C* and which is driven in the same way.

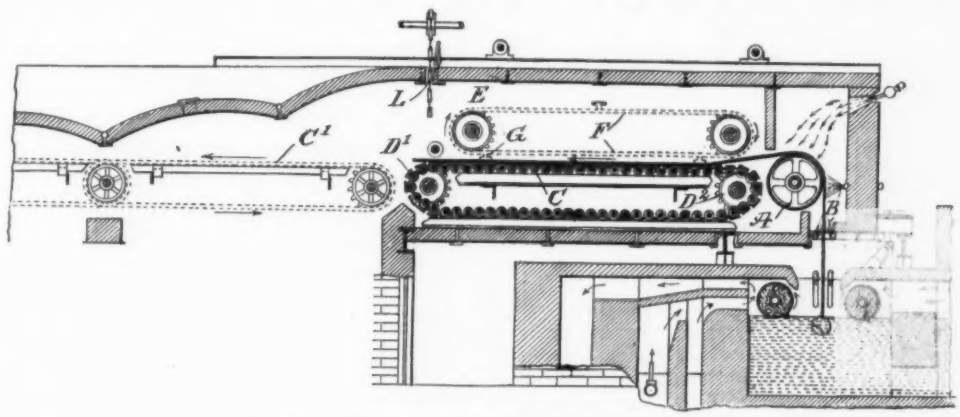


FIG. 8.—SECTIONAL VIEW OF THE MACHINE LEHR.

The second carrying-table extends throughout the entire length of the machine lehr. As soon as the glass has passed over the bending-roll *A*, its temperature is gradually reduced. When it passes from the first to the second carrying-table, it is hot enough so as not to be readily broken, and yet of sufficient firmness to bridge the gap between the two carrying-tables.

From the second carrying-table, the sheet emerges from the lehr and is received by a third or cutting-table which, as shown in Fig. 9 is similar in construction to the two carrying-tables. In other words it consists of parallel sprocket chains joined by slats to form a conveyer, the chains passing over sprocket-wheels driven from a main power shaft. At intervals in the chains, lugs *J* are oppositely disposed to form abutments against which a ruler may be placed, so that a diamond or other cutting tool may sever the sheet while it is in motion.

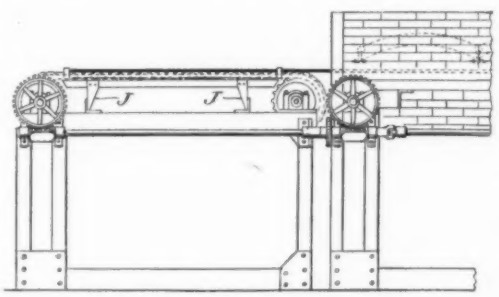
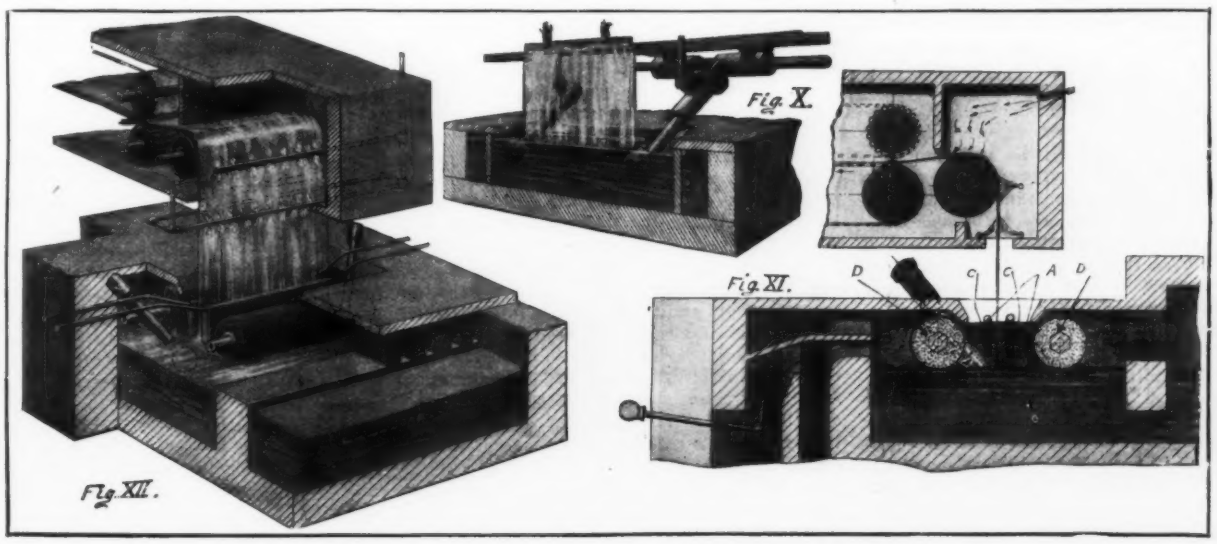


FIG. 9.—THE CUTTING TABLE.

In order to start the machine, a counterpoised bait depending from a chain driven by a sprocket is lowered through the opening *L* and dropped on the first carrying-table. By reversing the direction of the carrying-table's travel, the bait is conveyed and lowered into the molten glass and the carrying-table stopped. After a time the carrying-table is started again in the opposite or forward direction. As a result, the bait draws the glass vertically for about five feet, during which interval the sheet is bathed in fire, its temperature being so regulated as to bring it to a proper bending condition as it approaches the bending roll *A*. When the sheet is about to bridge the gap between the first and second carrying-tables, the bait is broken off from the sheet and hoisted by its sprocket to its idle position above the machine.

The machine here described draws a continuous sheet of glass 42 inches in width (although there is no limit to the width) at a linear speed of 56 inches a minute for single strength and 48 inches a minute for double strength. Contrast this with the speed of 12 inches a minute, which is the speed of blowing cylinders by the machine process for glass of medium thickness, and we see how great an advance Mr. Colburn has made in mere rapidity alone. Apart from the successful manner in which this machine operates, the process is remarkable for the quality of its product. The surface of the glass has a beautiful mirror-like fire polish far superior to the blown window-glass which we see every day. Even plate glass has a surface no better. Remarkable, too, is the way in which the spheres in the working chamber can be adjusted to produce glass of any thickness. We have seen specimens of glass made by this machine almost as thin as fine porcelain and other specimens almost as thick as plate glass.



THE COLBURN MACHINE FOR MAKING WINDOW GLASS BY THE SHEET PROCESS.

THE COLBURN WINDOW-GLASS MACHINE.

Nowhere is there to be found a better illustration of the physiological power which may reside in a certain definite grouping of elements than is seen in the case of protein. Gelatin, which resembles albumin in its superficial reactions and which contains approximately the same amount of nitrogen, is, as we know, quite incapable of taking the place of albumin in supplying the needs of the body for protein food. Yet, gelatin yields on decomposition many of the disintegration products furnished by albumin. Still, there are differences in the character and proportion of the cleavage products which, while not sufficiently marked to modify the ordinary protein color reactions, etc., are enough to indicate a difference in chemical structure, and owing to this difference in structure gelatin is quite unable to repair the waste of tissue in body metabolism. To every one at all familiar with protein chemistry the recent advances in knowledge of the hydrolytic cleavage products of this class of substances are more or less known. All proteins by appropriate methods of disintegration break down into a number of monoamino and diamino acids. Thirty

years ago these hydrolytic cleavage products were represented mainly by leucine, tryosine, aspartic and glutaminic acid; but now, as a result of efforts in many quarters, the number of such decomposition products has risen to at least seventeen. The significance of this statement is apparent when we remember that these cleavage products represent the building stones which make up the finished structure of the protein molecule, and if the time ever comes when we know all of these building stones, we shall then without doubt be able to construct or synthesize this most important substance.

MAGNITUDE OF THE LIGHTING INDUSTRIES.*

A REVIEW OF A GREAT INDUSTRY.

BY E. L. ELLIOTT.

ARTIFICIAL lighting ranks third in order of importance among the necessities of civilization, being superseded only by clothing and shelter. That the industries connected with the production and use of light should therefore present a large aggregate is readily apparent; and yet the real magnitude of these enterprises is doubtless far beyond the conception of those who have not had their attention particularly directed to the subject.

At the present time the production of artificial light can be divided into the following distinct classes: Candles, oil lamps, illuminating gas, electricity, and acetylene. This enumeration is in the order of their development. A candle is often used to symbolize an epoch, or a means of doing things, that has long since passed away; and it will doubtless come in the nature of a surprise to many to learn that the candle industry in this country at the present time is larger than it has ever been before, and is increasing regularly at the rate of about 10 per cent a year. This increase, of course, is due primarily to the large increase in population, which increases the total output of any commodity in general sale; but aside from this there are two factors to which the increasing popularity of the candle is largely due. The first of these is its use in religious celebrations. This use has come down from extremely ancient times, and is likely to persist for centuries longer. The use of candles in the rites of Catholic churches is a familiar fact to Protestants; but it will surprise many Christians of all faiths to learn that the use of candles forms an important element in the rites of the Jewish religion. For religious purposes candles are frequently made of enormous size. Mr. W. J. Calkins, the head of the candle department of the Standard Oil Company, to whom we are indebted for most of the information which we give on this subject, states that they have made candles 10 feet high, and capable of burning continuously for several years. From these giants the sizes and shapes vary through all dimensions down to a minute taper less than an inch long, and a quarter of an inch in diameter. Candles were formerly made in connection with the soap industry, but at the present time paraffin, a product of mineral oil, is the principal constituent, and hence their manufacture has been entirely separate from its original connection. The two materials used in the manufacture of candles are paraffin and stearin. The latter forms the principal portion of tallow, and has a considerably higher melting point than the former. The composition of candles is varied according to the climate in which they are marketed. Thus, for the southern markets a considerable portion of stearin must be used in order to make the candles withstand the natural heat without softening so as to bend or run down; while for the northern markets pure paraffin can be used; and for intermediate sections proportionate compositions. The pure tallow candle is practically a thing of the past, there being only one small manufacturer of such candles still doing a limited business in New York.

On account of the sentiment connected with its historical associations, as well as upon its very soft and small amount of light, the use of candles is increasing for decorative purposes. As a Christmas tree decoration, the candle is indispensable, and for the purpose of supplying the demand for such candles the Standard Oil Company alone runs three factories continuously the year round.

Aside from its use for religious and decorative purposes, the candle still finds favor for general purposes on account of its convenience and extreme portability. A statement of one of the great electrical inventors, which has been so often quoted as to doubtless be familiar to the reader, is to the effect that had the electric light existed for centuries, and the candle were to be newly discovered, it would be hailed as one of the greatest inventions of the age, being entirely self-contained, cheap, and extremely portable, and requiring no accessories in the way of chimneys or shades.

From their New York office alone the Standard Oil Company last year sold over 4,000,000 pounds of candles, while their total sales reached 30,000,000 pounds. The estimated value is 10 cents a pound, which gives an aggregate of $3,000,000. This represents, according to Mr. Calkins, about a third of the entire product of the country, so that a fair estimate of the total amount of candles used per year is 100,000,000 pounds, having a total value of from ten to twelve million dollars.

The manufacture of shades and candlesticks and candelabra is also an industry of considerable proportions, and one which is increasing at a fairly rapid rate. It has been impossible, however, to obtain any accurate figures, owing to the fact that the manufacture of such goods is one of the items among more general lines of manufacture.

The oil lamp, or as it is more familiarly known, the kerosene lamp, furnishes almost exclusively the light for the farmers and the inhabitants of villages and small towns at the present time. Before the discovery of petroleum in commercial quantities, the problem of light for this large class of consumers had begun to assume a serious aspect. The practical extinction of the sperm whale, which had been a source of illuminating oil in the years preceding, was already in sight, and there was no other immediate source which promised to furnish an available burning oil at a reasonable price. The drilling of a single experimental well in northwestern Pennsylvania in 1837 revolutionized the whole situation at a single stroke. It demonstrated that there was an entirely new source of supply; the extent of which could not even be surmised, but which was available in perhaps almost inexhaustible supply at a far less cost than attendant upon the production of illuminating oils which it was to supersede.

Petroleum had been known in Pennsylvania for many years previous to the putting down of this first well. It had been observed floating upon the surface of certain streams, and the census of 1810 reports the production of 550 gallons of this "spring oil" in Venango County. In 1890 there were 94 companies engaged in refining petroleum, having an aggregate capital of $77,416,290, and turning out an annual product valued at $185,001,198. In 1900, there were 67 companies, capitalized at $95,327,892, and turning out an annual product valued at $123,929,384. In 1899 there were produced 25,171,289 barrels of illuminating oils valued at $74,694,297. Assuming that the illuminating oils have the same general ratio to the entire product of the refineries as shown in 1890, the value of illuminating oil produced in 1900 would be $100,000,000, and if the production has increased at the same rate, the present annual value of illuminating oil would be $133,000,000.

The illuminating gas industry in this country dates from 1806, at which time David Melville, of Newport, R. I., lighted his premises by means of coal gas which he manufactured. This was nine years after the first experiments in England. Melville kept on improving his apparatus, and secured a patent in 1813, and later introduced gas lighting into a cotton mill in Watertown, Mass. New York city adopted gas lighting in 1823. Since that time the industry has been threatened with extinction by two strong competitors, namely, kerosene oil and the electric light. It has not only survived the competition thus introduced, but has shown a continuous growth up to the present time. At the time of its first introduction, illuminating gas was sold in New York at $10 per 1,000 feet. At the present time, the average price of gas throughout the United States is probably not far from $1 per 1,000 feet.

In 1890 there were 742 companies engaged in furnishing gas, with a capital of $258,771,795, and an annual product valued at $56,987,290. In 1900 there were 877 companies with a capital of $567,000,506, and products valued at $75,716,693. At the same rate of increase the annual value of the productions of the gas industry at the present time would aggregate $80,000,000. This includes all the gas used for heating, cooking, and lighting purposes. The best information obtainable gives the proportion used for lighting as 75 per cent, which would give a value of $60,000,000 as the annual value of illuminating gas.

The exact figures representing the capital invested, and annual production of electricity generated for illuminating purposes are impossible to obtain, owing to the fact that in the majority of stations at the present time current is sold for power and other purposes. In 1902 there were 3,620 central stations, the cost of construction and equipment of which amounted to $504,740,352, whose gross income was $85,700,605. These supplied 585,698 arc lamps, and 18,194,044 incandescent lamps. No authentic figures are available as to the amount invested in private isolated plants, but it is generally assumed, and doubtless with a fair degree of accuracy, that their total product is about equal to the product of the central stations. It is assumed by competent authority that there has been a 20 per cent increase in the output since the compilation of the figures given, thus bringing the annual product of the central stations to practically $100,000,000. It is also fair to assume that 75 per cent of this total is devoted to the production of light. We thus arrive at the round figure of $75,000,000 as the present annual expenditure for electric current produced by central stations for generating light; and assuming that the current privately generated is equal to this, we have the total of $150,000,000 as the annual value of electricity used for lighting purposes.

Of the industries engaged in the production of lighting apparatus, those in the electrical field represent the largest investment of capital and value of product. In 1905 there were reported 195,157 arc lamps produced, having a value of $1,574,422. The number produced during the past year probably was close to 200,000. In the same year there were produced 112,711,558 standard incandescent lamps, 1,584,495 miniature and decorative lamps. The value of the standard lamps was $6,308,294, and of the miniatures, $544,906. The value of this product was practically double that of the value of 1900; but the increase in the number of lamps during the same time was practically four times. It is conservative to estimate the increase in production and value since 1905 as 25 per cent a year, which would bring the total during the past year up to 168,853,869 standard lamps, and an aggregate value of $10,429,307.

In 1905 there were 784 establishments engaged in the manufacture of electrical apparatus and supplies, having a capital of $174,066,026, the annual value of whose product was $115,730,089. The value of the products shows an increase over 1900 of a little more than 10 per cent a year. On the same basis of increase the present value of the products would be $138,876,105.

The manufacture of lighting fixtures is an industry of large proportions. There were reported in 1905, 263 establishments making gas and lamp fixtures, having a capital of $20,206,975, and turning out a product valued at $17,560,386. In the same year electric lighting fixtures, including sockets and receptacles, etc., were valued at $5,304,466.

Of apparatus connected with oil lighting there were manufactured in 1900, 807,765 dozen glass lamps, valued at $1,498,675; and in the same year the lamp chimneys made were valued at $2,719,583, and the lantern globes at $497,021. Allowing for increase the present value must be about $3,500,000.

In 1905 the value of lamps and reflectors, which included metal lamps and their accessories, was $8,999,874.

We may then tabulate the several amounts, given in round numbers, as follows:

ANNUAL VALUE OF ILLUMINANTS.

Candles	$11,000,000
Kerosene	133,000,000
Illuminating gas	60,000,000
Electricity	150,000,000
Acetylene (estimated)	6,000,000
Total	$360,000,000

LIGHTING APPARATUS.

Electrical supplies	$139,000,000
Electrical lamps	12,000,000
Fixtures	18,000,000
Lamps and accessories	13,000,000
Total	$182,000,000

Taking 90,000,000 as the present population of the United States, we find that, according to the above figures, the cost of luminants for one year is equivalent

* Illuminating Engineer.

to $4 for every man, woman, and child. To say that 10 per cent of the light generated is wasted through misuse and ignorance is certainly a conservative estimate; this gives $36,000,000 as the total amount of loss from this source, or an average of 40 cents per capita for the entire population of this country. Aside from candles and kerosene oil, the waste is probably nearer twice this amount. If all items could be included which pertain to the lighting industry, it appears likely that the grand total of expenditure per year would reach half a billion dollars. A portion of this, however, is in the line of permanent investment.

GASES AND VAPORS.

A SIMPLE STATEMENT OF THEIR PHENOMENA.

BY PROF. O. N. WITT.

At one time the name of vapors was restricted to the emanations which rose from volatile liquids on the application of heat, and could be condensed to the liquid form by cooling, and the name of gases to substances which were in the gaseous state at ordinary atmospheric temperatures and which resisted all attempts at condensation. At a later period, after Thilonier and others had shown that many gases could be liquefied by cold and pressure combined, a distinction was made between coercible and non-coercible gases. It was then demonstrated by Andrews, whose researches and deductions have been completely confirmed by more recent experiments, that non-coercible gases do not exist and that it must be possible to liquefy any gas if a sufficiently high pressure and low temperature can be obtained. This law apparently annihilated the distinction between gases and vapors.

But the distinction remained in popular speech and its propriety is now again conceded by science. The distinction which is now recognized, however, is purely one of physical condition, not one of material substance. In other words, the same substance may present itself as a gas or as a vapor.

Guy-Lussac's law of the expansion of gases is expressed by the equation $V = V_0 (1 + a T)$, where V and V_0 denote the volumes occupied by a given mass of a gas at T degrees and at 0 degrees Centigrade (the pressure being the same in both cases) and a is the coefficient of expansion. This law is obeyed almost exactly by every gas so long as its temperature is much higher than the temperature at which it liquefies (at the pressure employed in the experiment), and for every gas under these conditions the coefficient of expansion is nearly the same and equal approximately to 1/273. Hence for all gases under these conditions the equation may be written $V = V_0 \left(1 + \frac{T}{273}\right)$. If we suppose the law to hold true down to the temperature of liquefaction, where the volume is reduced very nearly to zero, we find $1 + \frac{T}{273}$ nearly equal to zero or T nearly equal to —273 deg. C. For this and other reasons a temperature of approximately —273 deg. C. is called the absolute zero, and on the assumption made above the liquefying points of all gases should be very near this temperature.

But if any gas is gradually cooled, a point is reached below which the contraction becomes perceptibly greater than 1/273 for each degree of cooling and continues to increase as the temperature sinks. If the increased coefficients of expansion (or contraction) thus indicated are introduced into the equation, we shall have $V = 0$ at a temperature considerably above —273 deg. C. And as the rapidity of increase of the coefficient and the point at which it becomes perceptible vary with different gases it is evident that the temperatures of liquefaction (under the same assumed pressure) must be different.

Of course, the point at which this phenomenon—the increase in the rate of expansion—commences cannot be determined with great precision, but it is obvious that this point marks the boundary between the gaseous and vaporous states.

An "ideal gas," to use a term of recent introduction, is characterized by strict obedience to Gay-Lussac's law of equal dilatation and to the law of Mariotte (or Boyle), according to which the volume of a given mass of gas varies inversely as the pressure of the temperature remains unchanged. A vapor obeys neither of these laws with strictness.

Very few substances are ideal gases even at the mean atmospheric temperature of 15 deg. C. (59 deg. F.). At this temperature hydrogen and helium are unquestionably ideal gases, but oxygen and nitrogen have probably reached the lower limit of the ideal gaseous state, while chlorine, carbon dioxide, sulphur dioxide and most other gases show so marked a divergence from that state that they must, in strictness, be classed as vapors.

At one or another higher temperature, however, every vapor acquires the character of an ideal gas and, at all still higher temperatures below the point of chemical dissociation, the substance strictly obeys the laws of Gay-Lussac and Mariotte, and also the law of Avogadro, which expresses the fact that equal volumes of all gases at the same temperature and pressure contain equal numbers of molecules.

The transformation of gases into vapors at temperatures near their points of liquefaction is obviously a consequence of the essential nature of matter. We are ignorant of its mechanism and special causes, but they may, perhaps, be roughly sketched as follows: The molecules of a gas are pictured as perfectly elastic bodies which move, in virtue of their inherent energy, in straight lines, until they are deflected by impact against each other or the walls of the containing vessel. The conditions are similar to those of a great number of balls rolling in all directions on a billiard table, except that the motions of the molecules are not confined to one plane. Sir William Crookes, the Nestor of molecular physics, has compared the gas molecules to an imprisoned swarm of bees. If we imagine the bees to be untiring and elastic, so that they rebound after collision, the image is a fairly complete one. If the vessel is enlarged the bees will distribute themselves pretty uniformly throughout the larger space and will collide less frequently than before. If the space is contracted, the collisions will become more frequent. Now let us suppose that the bees, like real bees, lose energy and become fatigued. In default of other support, they cling to each other after collision, and the uniformity of distribution and the strict obedience to the laws of elasticity are destroyed. Soon all the bees cling together in one compact mass which falls to the floor of the prison. Here we have illustrations of the transformation of a gas into a vapor and the condensation of the vapor to a liquid. Another illustration is afforded by billiard balls covered with an adhesive substance which prevents them from rebounding after collision.

These illustrations suggest that the form of energy which is manifested in cohesion is peculiar to certain states of matter. It is not present in an ideal gas, but makes its appearance at the temperature below which the gas becomes a vapor. Gravitation between large masses, cohesion between molecules, and chemical affinity between atoms are only different forms of the universal force of attraction.

We know nothing of the atomistic state of matter, in which the atoms are not combined to form molecules. This state appears to be unattainable by human means, and since the development of the electronic theory it can hardly be even pictured in the form to which we had been accustomed. A molecular state of matter, in which the molecules exhibit no tendency to adhere to each other, is the state of an ideal gas. When cohesion commences and the molecules "coagulate," so to speak, the gas begins to be a vapor, and when the process of coagulation has been completed, the substance is a liquid or a solid. Of the molecular structure of liquids and solids we know nothing whatever.—Prometheus.

LIFE OF A RADIO-ACTIVE ELEMENT.*

By A. T. CAMERON.

A TYPICAL radioactive element gives rise continually to a radioactive product, together with one or more kinds of rays; radium gives rise to its emanation, and to α rays. In addition, heat in comparatively large quantity is continually liberated.

This continuous production of both energy and matter is explained by Rutherford by the assumption that atoms of the parent element are continually being broken down, or disintegrated, into simpler atoms, the heat and rays being the difference in energy-content in the two atomic systems. When guncotton is exploded a complex molecule is broken up into simpler ones, heat and light being also emitted. The two cases are parallel, the one being atomic, the other molecular.

It is found that the emanations, and many other active products, lose their activity almost completely in a measurable time. From studies of the rate at which the activity is lost, the conclusion is reached that in any one time a certain fixed proportion of the total number of atoms present spontaneously disintegrates. An actual illustration will make this clearer. The activity of any fixed quantity of radium emanation falls to half the initial value in approximately four days. In the second four days it falls to half of this second value, i. e., one quarter of the original. We therefore suppose that the emanation has decomposed to a corresponding extent. In the unit of time chosen, four days, the same quantity, one-half the amount at the beginning of that period, always disappears. Similarly in any other definite period of time a certain quantity, bearing a definite ratio to the original amount, will disappear. Again, at the end of eight days one quarter of the whole amount remains; at the end of twelve days, one-eighth; of sixteen days, one-sixteenth. But at the end of infinite time there will always remain some quantity, however small. Similarly, in all cases of active matter some remains undisintegrated after infinite time; the radio-active elements have an *infinite life*. Though they may have *died* for all practical purposes at the end of some measurable time, an unmeasurable but definite amount remains. However, we can always find when half a given quantity of active substance has disappeared. And it is this period which is termed the *half-life period* of such substances. It varies from four seconds in the case of actinium emanation to millions of years in the case of uranium.

Another term constantly used is the *average life* of a substance. It can be conveniently illustrated by a human parallel. A church filled with people on any fixed date contains a fair assortment of men, women, and children of all ages. If we know the total number of years each person will live after leaving that church we can calculate the *average life* of the congregation, counting from the definite time fixed by that church attendance. This is quite different from the *average life* of some number of persons from the time of birth of each, which is the basis of the data employed to calculate insurance rates.

The *average life* of a radio-active element at any definite time corresponds to the first of these illustrations. If we take a definite quantity of radium salt, then the atoms of radium it contains are of all ages. If they have just previously been separated from their uranium ore some may have been born only a few weeks previously, others have existed thousands of years, just as the church congregation may include infants and old men of ninety. Of the radium atoms a certain number will *expire* in a definite time, just as in so many years a number of the worshipers will have died. And we can calculate the average life of the congregation of atoms with as much certainty as that of people.

The application of the second kind of *average life* to radio-active substances was recently worked out in some detail by Sir William Ramsay as a lecture illustration. Though it has just been stated that the life of a radio-active atom is infinite, yet infinity is only a relative term; in this connection it only means a longer time than we can measure. It is extremely probable that just as the human life is measurable and definite, so is, let us say, the life of an atom of radium. One may go further. For there is much more regularity in the life of this dead matter; the life of human beings is variable, dependent on "all the ills that flesh is heir to," microbes, the bearers of disease, and accidents, the ills of fortune. We have no ground to suppose that the life of a radio-active atom varies from any similar cause. For example, the rate of decay—the death rate—of radium emanation is unaltered within the limits of measurement between the temperatures of —180 deg. and +1,600 deg. C. (90 to 1,870 deg. in the absolute scale), the extremes at which, so far, it has been experimentally tested. If this tremendous difference of temperature does not hasten the decay of a single atom of emanation we can at least postulate that its life is not easily influenced by external causes. So far experimental work has shown that we cannot hasten or retard the death of a radio-active atom; consequently we cannot alter its life. For its birth is but the death of its parent atom, to which the preceding statement likewise applies. And we are justified in stating that the average life of a radio-active atom, as used in the second sense above, is in all probability the actual life of that atom.

* Science Progress.

THE CORNU HELICOPTER.

HOW THIS NOVEL TYPE OF FLYING MACHINE WAS DEVELOPED.

THE type of flying machine which we illustrate herewith is one which has received considerable attention abroad, but which has, up to the present time, not been brought to any great degree of perfection. The experiments of M. Paul Cornu in this line of aviation are among the most scientific that have thus far been made, and they have resulted in the production of a machine which, in its entirety, has risen vertically from the ground a distance of several feet under its own motive power and carrying the inventor.

Starting his experiments with the model shown herewith, M. Cornu, after a successful performance in October, 1906, with the aid of 125 people who formed a stock company and subscribed $20 each, was enabled to continue experimenting and to build a full-sized machine, with which he hoped to win the Deutsch-Archdeacon $10,000 prize for a flight of a kilometer in a closed circle. This prize, it will be recalled, was won January 13 last by M. Henri Farman with his aeroplane.

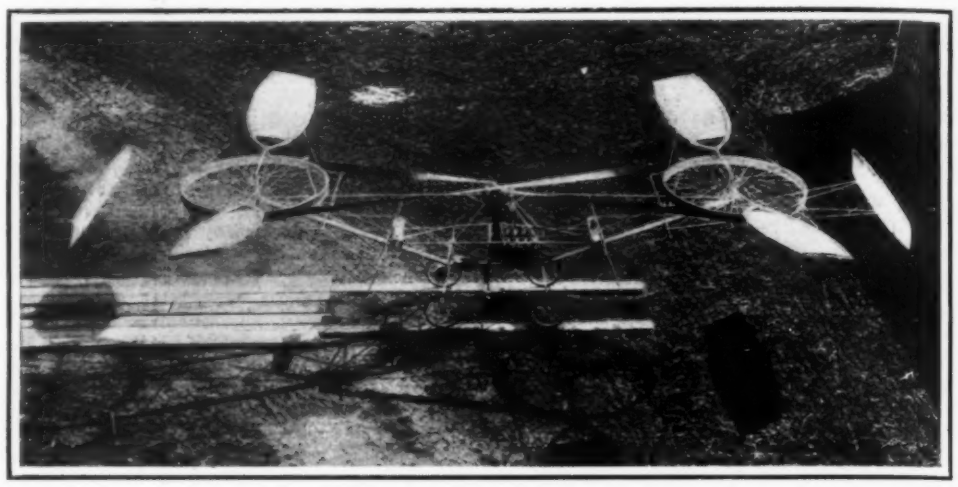
The model helicopter consisted, as can be seen from the photograph, of two relatively large propellers revolved in opposite directions by a 2-horse-power gasoline motor, and arranged to blow downward upon two small planes set at an angle from the vertical. The down draft of air upon these planes caused the machine to move along in a horizontal direction as soon as it had been raised in the air by the propellers. With the expenditure of about 1½ horse-power, the machine, the total weight of which was about 30 pounds, rose in the air and moved forward according to the expectations of its inventor.

In designing his man-carrying machine, M. Cornu at first had in mind the construction of a helicopter having a considerable number of small propellers driven at a high speed, but he later decided to copy the model as nearly as possible, and to make the large helicopter as large and light as he was able. Despite the apparent strong construction of the machine which we illustrate, the inventor has been hindered by the weakness of some of the parts.

The helicopter consists of a main frame in the shape of a wide U. This frame is made of large diameter, thin steel tubing, and each arm of it is reinforced by three sets of six small tubes each, placed at right angles to the main tube and having their ends connected by light steel cables forming a hexagon, while longitudinal guys also run from the outer ends of the large main tubes over the tips of the smaller ones. In the middle of the U-shaped frame thus formed, is mounted an 8-cylinder Antoinette motor of 24 horse-power. The frame is mounted upon four pneumatic-tired wire wheels. Its total length is 6.2 meters (20.34 feet) and its weight, including the four wheels, is 50 kilogrammes (110¼ pounds).

The aviator's seat is located at one end of the motor in the center of the frame. The motor is provided with a pulley for a 100-millimeter (3.93 inches) wide belt on this end, and this enables it to drive the two large wire-spoked pulleys that carry the propeller blades. The belt used is 22 meters long (72.18 feet). It passes over two pulleys located above the motor, and these feed it to the two large 1.8-meter (5.9 feet) pulleys, which it drives in opposite directions, since it is crossed, as can be seen from the illustrations. A jockey pulley, worked by a handle in front of the operator, acts as a clutch, and enables him to start and stop the propellers. The spark and throttle levers for the motor are also conveniently located. All the pulleys are mounted on ball bearings. A third of the way up one of the main tubes of the chassis is placed the 3-gallon water tank, while an equal distance up the other tube of the chassis is placed a 1¾-gallon gasoline tank. The water circulation is by thermo-siphon, and the gasoline is fed under pressure. The oil reservoir is above the motor, and the batteries and spark coil are placed beneath the aviator's seat.

The propellers consist of separate blades made up of silk tightly stretched upon frames of steel tubing. They are mounted upon the pulleys, which consist of rims of cast steel 1 millimeter (0.039 inch) thick and 100 millimeters wide (3.93 inches), mounted upon aluminium hubs by means of wire spokes. Their construction is similar to that of a bicycle wheel. The tubes forming the frames of the propeller blades are flattened progressively toward the tips of the blades, and are brought together at their inner ends and carried on a single piece of tubing, which extends in to the hub of the pulley and is pivotally mounted thereon as well as on the periphery of the same. The frames forming the propeller blades are covered with two layers of a special rubber-coated silk tightly stretched upon them by a special process. Their length is 1.8 meters (5.9 feet) and their greatest width 0.9 meter (2.95 feet). The blades themselves are not very strong, and it is only by bending them upward above the center and weighting them properly with small pieces of lead placed, after experiment, about two-thirds of their length out from the center, that it was found possible to balance the lifting force by centrifugal force; two cables fixed to the upper part of the propeller support the excess of this force.



PLAN VIEW OF HELICOPTER, SHOWING ARRANGEMENT OF MOTOR, DRIVING BELT, AND AEROPLANES AT ENDS.

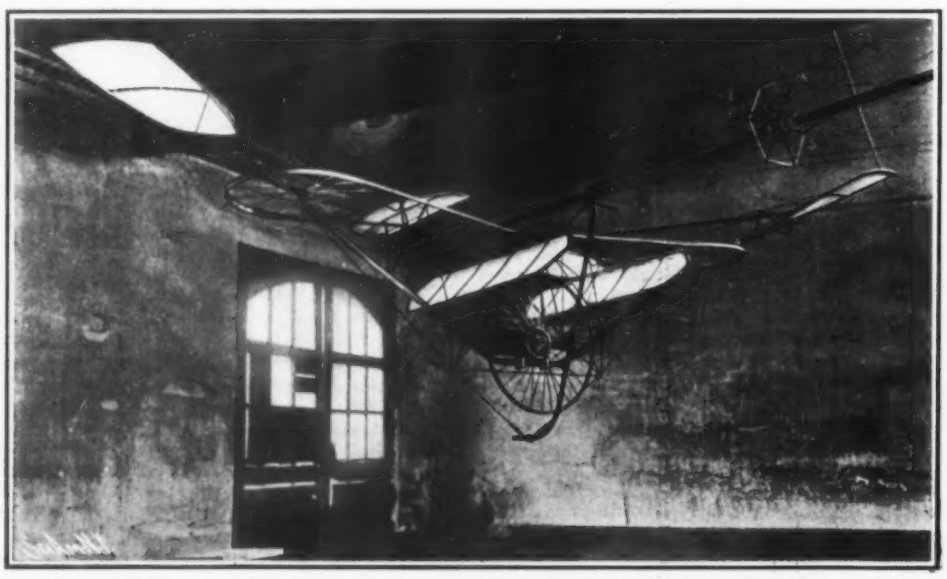
The propellers are 6 meters (19.68 feet) in diameter and make 80 R. P. M. The total weight lifted was 260 kilogrammes, or 573.2 pounds, so that the weight lifted per horse-power was about 44 pounds—the best that has yet been done.

The propellers are of variable pitch, and the changing of the pitch is accomplished by means of wire cables attached on one hand to the edges of the pulley, and, on the other, to the rearmost edge of the blade frame at about two-thirds of its length after first passing over a fixed pin on the forward edge of said frame. The system is double, in order to withstand the sudden strains produced in starting and stopping. Thus it can be seen the blade is entirely a tension member, and the pull on the cables, combined with the rotation of the inner ends of the blades, permits the variation of pitch. The total weight of a propeller complete is 24½ kilogrammes (54 pounds).

After it has risen in the air, the helicopter is propelled forward by the down draft of air against the two inclined planes located at each end of the apparatus. These planes consist of frames of flattened steel tubes covered with silk. They are 2½ meters (8.2 feet) long by 60 centimeters (1.97 feet) wide. They are arranged to pivot on a horizontal axis passing through their center from end to end, and mounted on two supports extending out from below the center of the pulley hub. The inclination of the planes causes the forward movement of the helicopter, while by swinging them around to the desired point, the machine can be made to turn to the right or left. They are arranged to be operated by two levers conveniently placed beside the operator. In making a circle, the planes are not set parallel with respect to the longitudinal axis of the machine, but they are both turned to one side or the other of said longitudinal axis, so that they are in line with two radii of the circle which the machine is describing. The total weight of these planes is 9 kilogrammes (19.84 pounds).

The construction of the full-sized helicopter was begun in December, 1906, and was only terminated in August, 1907, when the machine was given its first trial. The first point that was brought out was the necessity of balancing the propellers with great precision. The apparatus would be thrown about right and left as soon as the propellers came up to speed, and nevertheless weights of 55 grammes (about 2 ounces) placed at the end of one blade and of 75 grammes (nearly 3 ounces) on the other propeller, were sufficient to overcome this lack of balance. After the first trials had been completed, and the attempt was made to run the motor at its full power, trouble was experienced with the belt slipping, and to avoid this all the pulleys, both large and small, were covered with leather, for the big pulleys, despite their great surface, showed traces of slipping also. The pull of the wire spokes was so great as to form a series of slight hollows in the peripheries of the pulleys, which of course decreased the surface. It was not until after various changes had been made in the size of the driving pulley and the pitch of the propellers, that the helicopter operated successfully.

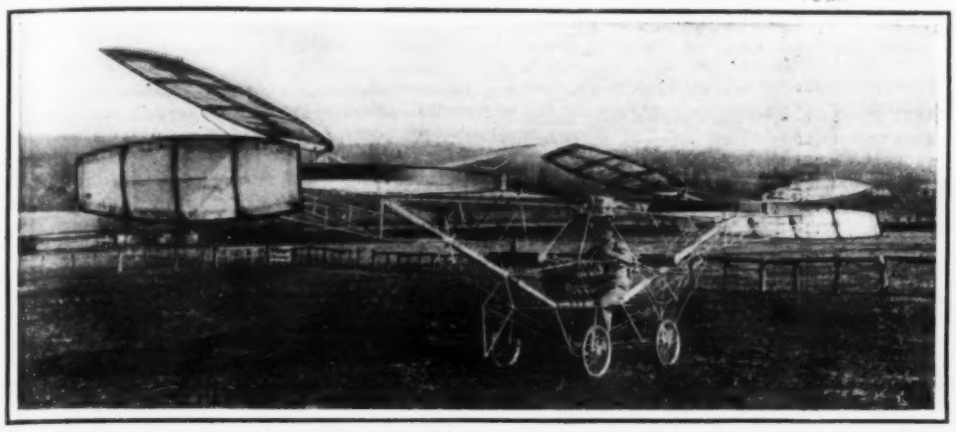
The first time that the machine rose properly from the ground was on August 31 last. The machine rose when the 6-meter (19.68 foot) propellers, the blades



CORNU'S MODEL HELICOPTER, WHICH OPERATED SUCCESSFULLY AND OF WHICH THE FULL-SIZED MACHINE IS A COPY.

This model weighed 30¼ pounds and was fitted with a 2-horse-power, opposed-cylinder, air-cooled gasoline motor. Suspended at the end of the long horizontal rod shown, it rose in the air and described a large horizontal circle with the expenditure of only 1¼ horse-power. The down draft of air upon the inclined planes caused forward horizontal motion. The amount lifted per horse-power—20 pounds—was no more than is usually obtained, and was no indication of what could be done—44 pounds—with a full-sized machine.

of which had 2.7 meters (8.86 feet) pitch, attained a speed of 70 R.P.M. The speed of the motor was but 750 R.P.M. A 50-kilogramme (110¼ pound) bag of sand was placed on the operator's seat. The machine rose, but trouble was experienced with the slippage of the belt, as before. After having tried three belts, and having increased the diameter of the driving pulley to 18 centimeters (7.086 inches), on September 27 the



THE CORNU HELICOPTER AS SEEN FROM ONE END.

The 8-cylinder motor, shown in the center of the machine, drives the two large pulleys by means of a belt. The aeroplanes seen at each end can be set at different angles in order to cause the machine to move forward from the air reaction of the propeller blades upon them.

whole machine and ballast, weighing 235 kilogrammes (518 pounds), again rose. The propellers made 85 R.P.M. and the motor 850, while the pitch of the propellers in this instance was 3 meters (9.84 feet). This apparent success did not last long, however, for as a result of increasing the pitch, the blades had to be loaded differently. As the centrifugal force was not sufficient, the blades buckled.

After the good results as to lifting had been obtained, the planes for forward motion and steering were fitted. A preliminary test was made on the 8th of October, and the machine was then taken to the factory of M. Pierre Duchesne-Fournet, about three or four miles distant from Lisieux, where a test of the completed helicopter was made on the 9th of November. In working order the machine itself weighed 203 kilogrammes (447.53 pounds), while the weight of the aviator was 57 kilogrammes (125.66 pounds), which brought the total up to 260 kilogrammes (573.2 pounds). The helicopter almost rose at the first attempt, but, as usual, the belt slipped. Next the driving pulley was covered with rubber, and on the 13th of November, for the first time, the apparatus and its inventor rose about one foot above the ground, and remained at that height for some moments, after which it gradually settled down to earth again, owing to the slipping of the belt. The screws made 90 R.P.M. and the motor 900, at which speed its designer claims that it will develop not more than 12 or 14 horse-power under the best conditions. The same day, in the afternoon, after the belt had been tightened, the helicopter again rose in the air and lifted its inventor; but the front part rose higher than the rear, and the inventor's brother, who had started the motor, hung on to the forward part of the chassis, and was also lifted a distance of about 1½ meters (5 feet). The aviator retarded the spark of the motor, and the machine came down gently to earth. The weight lifted in this instance consisted of:

The helicopter....	203 kilogrammes	or 447.53 pounds
M. Paul Cornu....	57 kilogrammes	or 125.66 pounds
M. Cornu's brother	68 kilogrammes	or 149.91 pounds
Total	328 kilogrammes	or 723.10 pounds

The inventor states that both he and his brother were so surprised at the sudden and strong lift produced, that they were not able to control the power of the motor and the speed of the propellers. They attributed the greater lift of the front propeller to a difference in speed, occasioned by the slippage of the belt on the rear pulley, and consequently they made special rubber bands to go around the large pulleys. After some modifications in the details of the apparatus, and after the strengthening of some of its parts, it was given another trial on December 4, a new belt being used on this occasion; but once again the slippage of the belt was the cause of the machine failing to remain in the air more than a minute. The equilibrium of the device appeared to be good on this occasion, for all four wheels of the helicopter left the ground simultaneously, and the machine rose as far as it was allowed to do by the four ropes which, after the experience of the 13th of November, it was deemed advisable to fasten to the corners of the chassis, in view of the fact that only the two MM. Cornu were operating the machine.

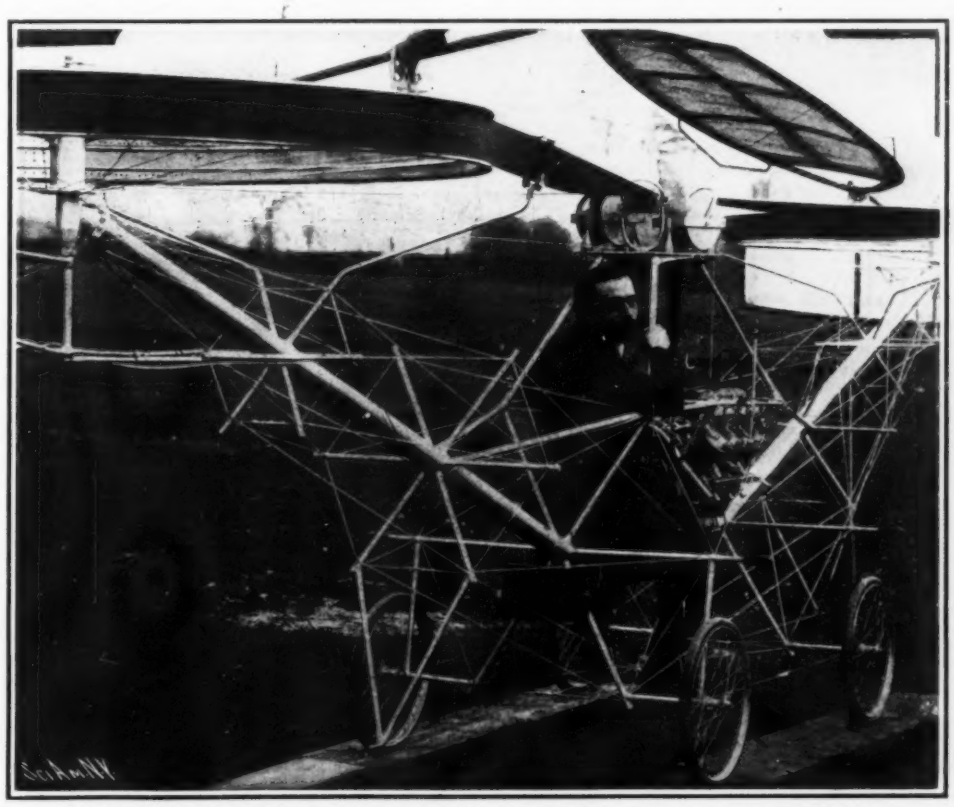
The success obtained made the Cornu brothers believe that they stood a chance of winning the Grand Prix for the first flight of a kilometer in a circle, if only they could overcome the slipping of the belt. They therefore continued their experiments; but the machine, strained by the sudden impulses given to the propellers by the tightened belt and the rubber coating of the driving pulley, showed signs of weakness. An axle was bent, and two of the propeller blades were broken. These were soon repaired, and they continued to experiment, with a view of finding some method of causing the belt to adhere to the pulleys without too great a tension being applied to it. Adhesives of different kinds, paper, etc., were tried without success. They finally turned to rubber, and had a special thin rubber belt manufactured for them in England. This was tried on March 30. There was no slippage, but other troubles developed. The propellers did not have the same efficiency as at the start, since they were no longer symmetrical, and as soon as the motor began to develop 10 or 12 horse-power, the whole apparatus vibrated intensely. Moreover, the prize had been won nearly two months previously. So, since they found the results already obtained sufficiently conclusive, they began the construction of a simpler helicopter, having modifications suggested by long experience.

As for the system of propulsion, the short duration of each experiment made it impossible to try this when the machine was in the air, but several tests were made of it with the machine on *terra firma*. The results obtained were as follows: With the propellers making 70 R.P.M., which was insufficient for the helicopter to rise, it would move forward or backward instantly as soon as the planes were inclined in either direction, and would develop a speed of 12 kilometers (7½ miles) per hour. The reasons why this speed was so low are given as follows: First, the inventor had not endeavored to find how fast the apparatus could be driven in this manner, as he was preoccupied chiefly with the problem of sustentation. Second, he believed that the speed of transmission can be increased by increasing the pitch, or the speed of rotation of the propellers. Practically, he was unable to do either of these things for the reasons given above. Theoretically, however, if the propellers had a pitch of 3 meters and turned 100 R.P.M., and if the planes were set at an angle of 45 degrees, the helicopter should travel along at the rate of 25 to 30 kilometers (15½ to 18½ miles) per hour. He believes it would certainly make 15 or 20 kilometers (9 or 12 miles), which would be sufficient at the start.

The following figures are given as to the results obtained: Total weight lifted, 260 kilogrammes (573.2 pounds). Power expended, 13 horse-power. Supporting surface of propellers, 6 square meters (64.583 square feet). Total weight lifted per horse-power, 20 kilogrammes (44.09 pounds). Weight lifted per square meter of supporting surface, 45 kilogrammes, or 9.21 pounds per square foot. Tractive force developed by the planes, 15 kilogrammes (33.06 pounds) as a mean. Ascensional force absorbed by the vertical reaction of the air on the planes, 7 kilogrammes, or 15.43 pounds.

The inventor believes that he was unable to obtain the results he set out to reach, not by a fault in the principle of his helicopter, but by a detail in its construction. The belt transmission was obligatory, in order to obtain the lightness and the small dimensions he desired. The size and diameter of the pulleys and the width and speed of the belt were all in accordance with ordinary practice, but the too great thickness of the belts employed was the cause of their slippage. As the power transmitted was scarcely over 10 horse-power, the efficiency was very great, which explains in part the large weight lifted per horse-power. A second cause of the high efficiency lies in the screws themselves, the blades of which were very sharp at their edges, and were covered with very tightly stretched silk, while their relatively small width facilitated their penetration of the air. It seems certain, according to the inventor, that if the full 24 horse-power could have been used, he would have been able to lift 350 kilogrammes (771.6 pounds).

The inventor believes, therefore, that it is quite unnecessary to make so large an apparatus in order to lift a man, and also that lightness is not indispensable. A good motor, first-class metallic propellers (silk or canvas gives too much in operation, and the propeller cannot be made to keep its shape, nor can it be regulated), and a well-arranged transmission on a simple and solid frame, should make certain the construction of an apparatus capable of lifting a man with an expenditure of a maximum of 15 horse-power, which, with a 24-horse-power motor, would leave ample power for propulsion. The critical point about such an apparatus is the propellers—their surface, their diameter, their speed of rotation, which are all points to be determined by experiment. The inventor is thoroughly convinced, however, that a helicopter having metallic propellers of small diameter, running at a high speed, must give excellent results; and this is the form of machine which he is now constructing.



NEAR VIEW OF THE CORNU HELICOPTER WITH THE INVENTOR IN THE AVIATOR'S SEAT.

This photograph shows the elaborately trussed frame, the 24-horse-power, 8-cylinder motor, the large horizontal pulleys driven by a 4-inch belt, a pivoted blade of one of the variable-pitch propellers, and one of the vertical planes which can be inclined for forward motion.

FORMATION OF MINERAL VEINS.—III.

THE MAGMATIC AND METEORIC METHODS.

BY DR. WILLIS EUGENE EVERETTE.

Concluded from Supplement No. 1688, page 303.

THE METEORIC FORMATION OF ORE-VEINS IN THE ROCKS.

60. (1) We have now studied the analytical composition and structural character of the rocks from the surface of the earth's crust, as well as learned the kind and amount of metals which we can commercially and economically obtain from these rocks. (2) The next question that naturally arises is, By what method of deposition were the veins and deposits of ores formed in the rocks, from which we have extracted the heretofore described metals. (3) However, in order to give mining geologists and mining engineers a fair idea of the petrographic character of the rocks in the country which I am first going to herein cite as an evidence of the meteoric water formation of metallic gold, in deposits of originally non-auriferous placer gravels, I herewith give my report on the geology of the Klondike-Yukon gold placer region, including my report on the meteoric water genesis of the formation and deposition of the metallic gold content as found in the placer gravels of the Klondike-Yukon northland—as formerly published in the SCIENTIFIC AMERICAN SUPPLEMENT No. 1669 of December 28, 1907; No. 1670, January 4, 1908, and No. 1673, January 25, 1908, in relation to the formation of a "Laccolith."

61. (1) Thus we see how gold, both as a metal and as a mechanical combination with sulphur and iron, can be formed by meteoric alkalinely-silicated waters in these placer gravels after these aforesaid gravels had been torrentially deposited as a non-auriferous gravel bed. (2) Now we can go one step farther, and then see that if these highly thermic meteoric and alkalinely-silicated waters are forced by the same pulsating seismic energy into the cracks, crevices, fractures, and porous strata of the rocks in the surface of the earth's crust, precisely similar conditions will arise, to cause a precipitation and cementation of the minerals and metals thus held in aqueous solution, and the consequent result would be the formation of a mineral deposit, or a vein of ore.

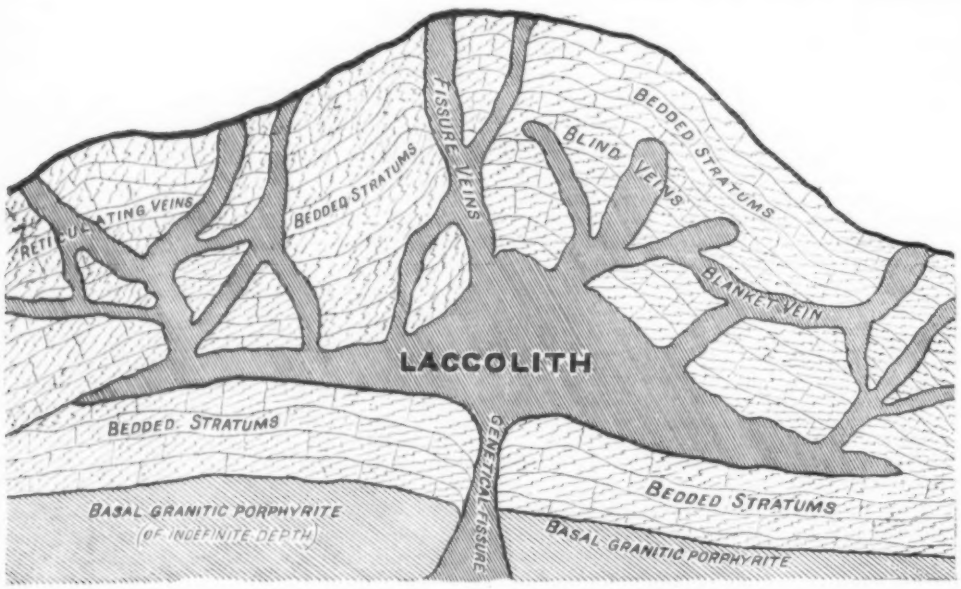
62. (1) But all mining geologists and mining engineers have many strong proofs of another method of mineral deposition, by which ore veins may have been formed among the rocks, in addition to the meteoric method of the formation of mineral veins and ore deposits. (2) This method has been called the magmatic method of ore genesis, on account of the gaseous condition of the aqueous oxygen and hydrogen in the magma of the molten rock, and is especially suited to the deeper fractures and crevices of the rocks which are far below the surface; which fractures must undoubtedly have been formed during the violent torsion, shearing, and squeezing of the deeply-seated rock strata at the time of any general seismic activity with its usual accompanying pulsating volcanic action.

THE MAGMATIC FORMATION OF ORE VEINS IN THE ROCKS.

63. (1) We have heretofore shown that meteoric waters are those waters which have fallen from the air back to the earth from where they were formerly lifted up by evaporation, or by the expansive power of the heat produced by the action of the waves of vibrative energy from the sun, being strongly resisted by our atmosphere, in passing to the earth and causing the phenomena of sunshine heat. (2) We also know that this meteoric water can only sink into the earth among the crevices and porous strata of the rocks to a certain distance, where the normal 1 degree Fahr. of increase of temperature for each 70 feet vertical in depth will increase the local temperature of the rocks, so as to be sufficient to overcome the action of the increase of inter-terrestrial pressure and its consequent increase of density and increased boiling point, so as to again expand the descending meteoric water, re-evaporating it into a steam or gas, so that it will not obey the downward natural law of gravity any farther, but tends to remain at a certain level or zone in a steamy, vapory, intensely heated gaseous state. (3) Some proof of this statement exists in the finding of dry, dusty ore bodies below the permanent water levels of certain deep mining shafts in Michigan, Montana, and Colorado. (4) But then the important question naturally arises, From where comes the enormous amounts of liquid water, as well as the clouds of vapory steam or gaseous water, that are always and invariably seen during every violent volcanic outburst and eruption? (5) The learned researches of Rosiwall, Suess, and Hill call to our close attention that we cannot account for all of the volcanic waters from the small quantity of the meteoric rainfall that comes on our earth. For in fact, these learned students of the genesis of meteoric waters actually seem to conclude that even the waters of the oceans have been formed, originally, from the enormous amounts of oxygen and hydrogen gases that were evolved and ejected in the erupted magma from primeval volcanoes during the genesis of the formation of the present crust of our earth. (6) It does not seem physically possible that water, when ejected from the far inland volcanoes, such as are in the Andes ranges, has any direct connection with the water from the bottom of any ocean (or from any vast body of inter-terrestrial lakes of water) to give forth the cubic miles of water that are ejected by volcanic energy. (7) If we presume that hydrochloric acid gas exists in great quantity—and we have reasons to presume this to be true—as a compound of, and among, the deeply-seated rocks far below the surface of the earth's crust, we can then understand from where this magmatic water comes. (8) For, when violent seismic energy produces deep fractures from the far distant and intensely heated rocks to the surface, the sudden release of the normal pressure and the consequent release of the excessive density of these intensely heated interterrestrial rocks would cause the instant formation of highly liquefied rock, which would be violently pulsated up into the atmosphere—as its least resistance—far beyond the earth's surface from up this deep fracture, and the molten volcanic rock be attended with enormous volumes, cubic miles in extent, of gaseous hydrogen, and gaseous chlorine and gaseous oxygen into the nitrogen-oxygen gas of the atmosphere—the air; and an immediate formation of hydrogen-oxygen gas would take place, that in cooling and condensing into a liquid would form water—the freed oxygen and chlorine being afterward absorbed by alkalies and petrolic and organic matter. (9) Van Hise has shown us, in his admirable Butte, Montana, researches, that molten rock and water are miscible to any and every degree. And it may be probable that these erupted interterrestrial gases of magmatic oxygen, hydrogen, and chlorine (that are always emitted along with the furiously bubbling and boiling molten volcanic rock) may be the cause of the visible steamy vapors we see always arising from any volcanic activity, and be also the cause of the consequent formation of water therefrom, as well as to account for the phenomena of the crystallization and cementation of the rocks and minerals that we find in the thereafter cooled crevices and fractures among the rock-mass of the earth. (10) This theory would practically mean that the genesis of an ore vein in the rocks of the earth was by definite magmatic action, and had nothing at all to do with the theory of the depositing action of descending meteoric waters, except as an enleanment or as an enrichment in the originally formed magmatic ore veins.

64. (1) Geologically, we all understand what Winchell describes as a laccolith. May not the filling up of the genetical laccolithical fissure in the deeply basal rocks and the consequent filled-in vault-shaped upthrust among the bedded strata, have been formed by magmatic aqueous action—the seismic uplift of the strata not quite fracturing and reaching to the surface of the earth? It certainly seems that this is true. (2) I herewith illustrate the formation of a laccolith as published in my article thereon in the SCIENTIFIC AMERICAN SUPPLEMENT of January 25, 1908. (3) If the laccolith (and its upper radiating fractures filled as ore veins) has been formed by magmatic deposition and cementation, we can understand then, after passing the permanent water level of the descending meteoric water (or the ground water of certain mines) why the deeper levels have become hard and dry, and are often found hot and dusty. (4) Finch has shown in his experience of geological study of certain mines in Colorado, that certain ground waters were limited to only about a thousand feet below the surface. (5) It is possible that this level of ground water varies in depth to even as far down as below the beds of the oceans, rising nearer to the surface of the earth as distance from the ocean floor takes place. (6) Posepny calls attention to a "vadose" region, i. e., that particular deposit of rocks which extend from the earth's surface downward to the permanent water level. And, seemingly, the ore-forming activity and the oxidizing action of the descending meteoric waters is practically confined to this vadose region, or to the region of aerial or meteoric water, absorption, precipitation, and oxidation of the mineral content of the rock mass.

65. (1) As mining geologists and as mining engineers, we nearly all can agree that wherever volcanic action has been attended with intrusive rocks among the bedded strata, the period of ore formation in the crevices and fractures among these bedded strata seems to have taken place almost immediately after the cooling and crystallizing of the intrusive molten eruptive rock. (2) Many of these intrusive rocks accompanied by their magmatic aqueous vapors did not reach up through the bedded strata to the surface, as beautifully shown at the base of some of the contorted stratified bluffs in the valley of the Yukon River of Alaska; and thus they may have caused laccoliths and sub-terrestrial deposits of ores, as well as formations of ore veins, in the deep fractures of the far distant rocks from the surface, that may, by seismic convulsions, disintegration, and volcanic upheaval, be the future surface ore veins, that will be mined by the peoples who will come on this earth after our entire civilization and population has been annihilated and disappeared.



VERTICAL SECTION OF LACCOLITH, SHOWING THE GENETICAL FISSURE, AND THE RADIATING UPWARD FISSURES, IN THE BEDDED STRATA.

These fissures are filled with ores, quartz, and lime spar, which were deposited by the thermal pulsating springs of alkalinely-silicated waters rising from the laccolith, while under volcanic pressure and heat.

RECAPITULATION.

66. (1) Therefore, we may certainly consider that, primarily, the genesis of the ore veins in the fractures of the rocks in the crust of the earth was by an original magmatic origin and magmatic form of mineral deposition and cementation, from below the vadose region to great depths deep down in the rock mass, as well as also in many portions of the vadose region itself, up even to the surface of the earth. (2) And, secondarily, the formation of ore veins and mineral deposits by the action of meteoric waters in the vadose region (i. e., from the bottom of the permanent water level to the surface) was principally as an ore enrichment or as an ore enleanment of the primary formed magmatic ore veins; and also as a gravel enrichment, such as I have heretofore described in the genesis of the secondary formation of gold, pyrites, and silica (from meteoric alkalinely-silicated waters) in the placer gravels of the Klondike-Yukon northland.

67. Secondary action (as ore enleanment and ore enrichment of the originally-formed magmatic ore veins and mineral deposits) was undoubtedly produced by the dissolving, depositing, and cementing changes brought about by the percolation of highly thermal alkalinely-silicated meteoric waters, in and throughout the crevices, fractures, and porous strata among the rocks of the crust of the earth belonging to the vadose region; and, no doubt, in many recently volcanically active districts took place far below the now permanent meteoric ground water of vadose ore veins.

68. Therefore, when we fully realize the importance of the leaching, depositing, and cementing action of the highly thermal alkalinely-silicated meteoric waters among the vadose rocks of the crust of our earth, as mining geologists, mining engineers, mine managers, and practical miners, we may then much better understand the reasons for the perplexing causes of so many rich ore veins and lean ore veins being found (sometimes even very near each other) in certain of our working mining districts.

69. Thus the practical study of the rocks of the earth's crust is an intensely interesting study, both from the economic and commercial side, for operative mining men and engineers, and also to the working field geologists and students of mineralogy.

HOW THE EARTH IS WEIGHED.

THE MIGHTY MATHEMATICAL SCALES OF PHYSICS.

BY PROF. POYNTING.

STRICTLY speaking, the earth has no weight, since for every piece pulled in one direction there is another equal piece pulled equally in the opposite direction.

We can, however, imagine a weighing experiment which would give us, in a certain sense, the weight of the earth, though the imagined experiment is quite impossible in practice. Suppose a pair of scales set up here, and suppose that each cubic foot of the earth is brought up in turn, weighed and then put back into its place. The total of the weights of all these pieces may be called the weight of the earth.

If these weighings could be made the total weight would amount to about 12,500,000,000,000,000,000,000,000 pounds. If the earth had throughout the density of water each cubic foot would weigh about 62½ pounds. The actual earth would, *on the average*, weigh about 350 pounds per cubic foot, or about 5½ times as much as if it were water. This is expressed by saying that the mean density of the earth is about 5½.

Instead of speaking of the weight, it is better to speak of the mass of the earth. The weight of any piece of matter, its heaviness, or the pull of the earth upon it, varies from place to place. It is, for instance, about 1 in 300 greater here than at the equator. But its mass, which measures the difficulty of getting it into motion, is the same everywhere. A piece of brass or iron marked as 1 pound has one pound of mass wherever it is. When we weigh out a pound of sugar or a pound of tea we are really making use of the fact that equal weights *at the same place* have equal masses, and we are obtaining a pound mass of sugar or tea. We ought to describe the earth as having so many pounds of mass, not weight.

Since direct weighing of the earth is impossible, we must use the property of gravitation to find its mass. Newton established the law that any piece of matter pulls any other piece with a force proportional to the mass of each and inversely proportional to the square of the distance between them. Thus, if the moon were taken twice as far away, the earth's pull on it would be a quarter of what it now is; if it were taken three times as far away the pull would be one-ninth. If, again, the earth's mass were doubled the pull would be doubled. It would be doubled too if the moon's mass were doubled, and if both masses were doubled the pull would be four times as great. If the same piece of matter is acted on at the same time by two bodies, *A* and *B*, the pull by *A* on it will bear to the pull by *B* on it the proportion which the mass of *A* divided by the square of its distance bears to the mass of *B* divided by the square of its distance.

Suppose we hang up a weight at a place on the side of a mountain. The earth pulls it straight down, while the mountain pulls it to one side, and the horizontal mountain pull is to the vertical earth pull as the distance the weight is drawn aside to the vertical length of the suspending string. If, then, we can measure how much the weight is drawn aside, and can measure, too, how far away all parts of the mountain are, since the earth is at the average 4,000 miles away, we can calculate how many times greater is the mass of the earth than the mass of the mountain.

Or suppose we hang a weight from one side of a balance and counterpoise it. The earth pulls it down. Now, suppose we bring a large mass underneath the hanging weight, say, on the average one foot away. Its pull is added to the earth's pull. If we can measure this extra pull, knowing the distance of the earth, 4,000 miles, and the distance of the large mass, 1 foot, we can calculate the mass of the earth in terms of the large mass brought underneath. In an actual experiment a weight of 50 pounds thus hung from a balance became heavier by 1 in 90 million when a mass of 350 pounds was brought under it at an average of 1 foot away. The earth, on the average 4,000 miles or twenty million feet away, pulled the hanging weight ninety million times as much as the 350 pounds. If the whole earth could have been placed one foot away its pull would have been twenty million × twenty million times as great. So that the mass of the earth is twenty millions × twenty millions × ninety million times 350 pounds.

It is possible to weigh the earth by either of these methods.

The first experiments in earth-weighing were made by Bouguer about 1740 in South America. In one experiment he swung a pendulum first at sea level and measured its swing-time. Then he swung the same pendulum at Quito, a place on a table land 10,000 feet above the sea, and again measured its swing-time. He could calculate from the first swing-time what would be the swing-time 10,000 feet up in the air without any intervening land merely from the increased distance from the center of the earth. The actual swing-time at Quito was rather less than this through the pull of the material composing the table land. So

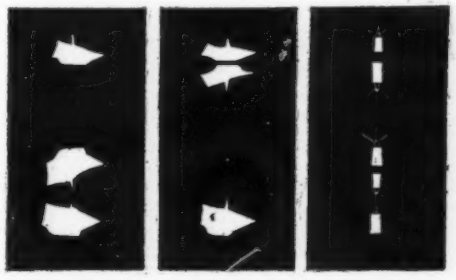


FIG. 1. FIG. 2. FIG. 3.

THEORY OF THE MIRAGE.

the experiment should give the mass of the earth in terms of the mass of the table land.

In another experiment he hung a plumb line at the side of a mountain, and measured how much the mountain pulled it away from what would have been the vertical had the mountain been absent. The earth pull was as many times greater than the mountain pull, as the plumb line was longer than the distance the plumb bob was drawn aside. Allowing for the distances away of the earth and the mountain by the inverse square law, the experiment should give the mass of the earth in terms of the mass of the mountain.

Bouguer's experiments were carried out under great difficulties, and his results were quite wrong; but he was the first to show that earth-weighing is possible.

The next experiment was made by Maskelyne in 1769 at Mount Schiehallien in Scotland. He hung a plumb line at the south side of the mountain and found that the bob was pulled to the north, and then took it to the north side and found that it was pulled to the south. The inclination of the two plumb lines through the mountain pull was about 12 seconds, or 1 in 15,000. He calculated that if the mountain had been as dense as the earth, then, allowing for distance, the two directions of the plumb line would have been inclined through the mountain pull about 21 seconds or 1 4-5 times the observed amount. Hence the earth is about 1 4-5 times as dense as the mountain. But from pieces of the rock composing the mountain its density was estimated at 2½ times that of water, so that the density of the earth came out as 2½ × 1 4-5 = 4½ times that of water.

The next experiment was made by Cavendish in 1798. His method was quite different. He hung up two small lead balls, each about 2 pounds, at the ends of a light wooden rod about 6 feet long suspended horizontally by a long thin wire. Two large lead balls, each about 350 pounds, were then brought up one in front of one of the small balls and the other at the back of the other small ball; their attractions pulled the rod slightly round, and the actual pull exerted could be measured from the angle through which the rod turned. The distance between the centers of the attracting and attracted balls was about 9 inches. Allowing for the distances of attracting ball and of the earth, the mass of the earth could be determined in the terms of the mass of the large balls. Cavendish found the mean density of the earth to be nearly 5½ times that of water.

Several repetitions have been made by Cavendish's method. One of these, carried out by Boys, is probably the most trustworthy yet made. He found that the mean density of the earth is 5.527.

The common balance has also been used by several workers. In an experiment made by the lecturer a large balance with a four-foot beam was used, and round weights, 50 pounds each, were hung on each side. A sphere, weighing 350 pounds, was then brought under one of the weights and made it heavier, so that the balance tilted over slightly. The tilt was measured and found to be due to an increase in weight of the 50 pounds by about one ninety-millionth of its weight. The center of the 350-pound sphere was one foot below the center of the 50-pound sphere, while the earth was twenty million feet away on the average. Hence, the earth's mass was found in terms of the mass of the 350-pound sphere. Its density came out just under 5½ times the density of water. The rocks on the surface of the earth are usually of density about 2½; the ocean is of density 1, so that the interior of the earth must be very much denser than the crust.

"A History of the Methods of Weighing the Earth" is given in the Proceedings of the Birmingham Philosophical Society, vol. ix., part 1, 1893.

A full account of all the experiments made up to the date of publication is given in "The Mean Density of the Earth," by Prof. Poynting.—Syllabus of a lecture delivered at the University of Birmingham.

THEORY OF THE MIRAGE.*

THE theory of the mirage forms the subject of several recent papers by Prof. Antonio Garbasso. In notes contributed to the Atti dei Lincei, xvi. (2), 1, 8, the author discusses the propagation of light in a heterogeneous medium, making use of the principle of least time, and considering the case of space of any number of dimensions defined by curvilinear co-ordinates. The space in question in supposed to be subject to the usual assumption that the square of the line-element is a homogeneous quadratic function of the differentials of the co-ordinates. As might be expected from the principle of least action (an analogy the applications of which to the problem are probably already known), the equations of the path can be reduced to the form of the ordinary equations of dynamics by a suitable choice of the characteristic function. The applications to the mirage itself are discussed in a paper in the Memorie of the Turin Academy, 1907. Prof. Garbasso claims that while the phenomenon has been studied both experimentally and theoretically, his present work fills a gap in the literature by establishing agreement of a quantitative character between the results of calculations and those of experiment.

Two kinds of mirage are distinguished, one due to the variations of density caused by diffusion between two fluids of different refrangibility initially having

* Nature.

a plane of separation; this is called the mirage of Vince. The second kind, called the mirage of Monge, depends on diffusion outward from a plane boundary maintained indefinitely at the same conditions. The former condition gives three images, two direct and one inverted; the latter gives only the reflected image. Prof. Garbasso calculates the law of density from the equations of diffusion, and thus determines the equations of the trajectories of the rays of light and the form of the wave-front.

The final comparison with experiment is discussed in a paper by Luigi Rolla, also in the Memorie of the Turin Academy. In it the last-named author describes experiments showing how, not only has Wollaston's original artificial mirage of the Vince type been reproduced with its three images, but also the Monge mirage has been imitated, and in both cases the trajectories of the rays have been determined by observation and compared with results of theory. Moreover, a mirage with five images, observed by Parnell at Folkestone in 1869, was realized by placing over a layer of carbon bisulphide a mixture of equal parts by volume of alcohol and chloroform. Owing to the unequal rates of diffusion, the conditions give rise to five images, and this and other experiments are shown to be suitable for lecture-room demonstration.

By taking a block of gelatin containing a cavity filled with liquid which gradually diffuses into the gelatin, the corresponding images for a cylindrical or spherical distribution of density have been also produced and compared with the results of mathematical calculation.

The first and second figures show the mirages of a diaphragm somewhat in the shape of a ship produced by the medium formed by diffusion between alcohol and bisulphide of carbon. Fig. 1 represents the appearance after a few hours. Fig. 2 after several days. Fig. 3 shows the five images obtained by diffusion between bisulphide of carbon and a mixture of alcohol and chloroform.

ENGINEERING NOTES.

In the discussion of one of the papers presented before the December meeting of the American Society of Mechanical Engineers, it was stated that the limit of superheating desirable for Corliss engines is 500 deg. F. If the [illegible] is used at a higher temperature, the valves warp and bind, due to their unsymmetrical form, and in some cases, cylinders have been known to change their shape sufficiently to cause difficulties. In engines fitted with ordinary slide valves, no difficulty is experienced, except with lubrication, but this has, in some cases, been overcome by direct oil connections to the valve seats.

Electricians are precise and scientific; they can tell us, within ½ per cent, what the efficiency of an electric motor is. The mechanical engineer looks upon electricity simply as a convenient method of power transmission, comparable to a belt, a rope, or a shaft; but when you ask the mechanical engineer the efficiency of a line shaft, of a rope or a belt drive, you receive the reply: "I don't know." In this, the electrical engineer has a decided advantage; he knows, and tells everybody that his electric motor has an efficiency of probably 85 per cent, and the natural inference is that belts or ropes must have a lower efficiency because nothing is said about them. As a matter of fact, rope drives have about 95 per cent efficiency, depending upon the number of ropes and the style of drive. It is to be regretted that reliable tests of rope and belt-drive efficiency are so seldom made by manufacturers and transmission engineers. The question of efficiency being decidedly in favor of belts or ropes, it follows that electricity should not be used as the only means of power transmission, but that engineering judgment should be exercised in determining the power to be used.

The United States Forest Service made some time ago a thorough study of the relation existing between moisture and the strength of wood. The results of its investigations are interesting and instructive. It has been found that the relation of moisture to strength follows a definite law. The strength of all kinds of wood increases rapidly with proper drying, the amount of increase depending on the species and the degree of dryness. Thus the strength of a piece of unseasoned red spruce may be increased over 40 per cent by a thorough drying at the temperature of boiling water. But the strength decreases again as the wood reabsorbs moisture. Air-dried wood protected from the weather, and containing 12 per cent of moisture is, according to species, 1.7 to 2.4 times stronger than when green. Drying also increases the stiffness of wood. These conclusions have been drawn from pieces of small cross-section, not exceeding 4 inches by 4 inches. Large timber requires years of drying before the moisture is reduced to the point at which the strength begins to increase. It has been found that under normal conditions wood fiber will absorb a definite amount of moisture. Additional water only fills the pores. It has also been found that the water which simply fills the pores has no effect on the strength. The fiber saturation points are: For longleaf pine, 25; red spruce, 31; chestnut, 25; red gum, 25; red fir, 23; white ash, 20.5; Norway pine, 30 per cent, estimated on the dry weight of the wood. Timber that has been dried and resoaked is slightly weaker than when green.

ELECTRICAL NOTES.

A dispatch from Berlin states that the Wireless Spark Telegraph Company has transmitted a message between its station near Berlin and the Hamburg-American liner, "Cape Blanco," off Teneriffe, a distance of 2,290 miles. Wireless communication has been established between the coast of Morocco and Paris, France, the Eiffel tower station communicating with warships on the coast of northern Africa, a distance of nearly 1,200 miles.

The German navy has ordered one of its ships to be fitted with an electric propulsion system of the Siemens-Schukert type. According to this system, the power generated in the engines—in this case steam turbines—is converted into electric energy, and part of it is stored in accumulators and is utilized as occasion may require. It is not stated what advantages are expected to be derived by this system, excepting, possibly, greater flexibility of the power. The steam turbine alone, of course, drives the propellers at too high speed for economical working, whereas if the steam turbine is used at a high speed revolution, and corresponding high efficiency, and electric power transmission, with low rotating speed of the propellers, is employed, greater economy is obtained. The propellers can be controlled directly from the bridge by this method, which, of course, would be a decided advantage.

The management of the Belgian State Railroads, after long investigation, has decided to use direct current and the third rail on several miles of road at the Parc de Laeken, near Brussels. This decision was made in accordance with the recommendations of a report by E. Uytboreck, electrical engineer of the government railroads, who some months ago visited the United States and spent considerable time investigating the operation of the New York Central, the New Haven, and other installations, visiting manufacturing companies and fully acquainting himself with the state of direct current and single-phase development in the country. The Belgian government have been given a license to use the Wilgus-Sprague type of protected third rail, and orders for much of the necessary materials have already been placed. The road on which this installation is to be made is new, but it is understood that this is the initial step in the electrification of certain lines near Brussels.

Motors for intermittent steel mill work require a design quite different from that used in any other class of service. They are not only subjected to heavy intermittent duty, large starting and accelerating torques, and shocks due to sudden variations of load, but they must also withstand rapid and continued reversals. Some of the features of up-to-date direct-current mill motors are as follows: Strong cast steel horizontally-split frames provided with heavy wide-spread feet; the upper frame should be hinged to the lower one and the connections so designed that the motor can be easily opened and armature removed without changing electrical connections; axle-bearing housings, when required, should be cast with and form part of the lower frame; large mechanical clearance between armature and fields should be provided; the armature bearings should be split, interchangeable, dust proof and provided with eye-bolts for handling the armature; provision should be made for either grease or oil lubrication; shafts should be extra large compared with those used in railway service and the armature should be built upon a spider so that shafts can easily be replaced; the insulation should be as nearly fireproof as possible, and capable of withstanding the high temperature to which it may be subjected, due to its own heating and the high temperature of surroundings; the motor should be inclosed and provided with tapered shaft extensions on both ends for brake and pinion fits.

It is proposed to carry out the extraction of nitrogen from the air on a large scale in Norway. A large company known as the North Electric at Nottoden has recently made a combination with a well-known firm, the Bavarian Aniline and Soda Works, of Ludwigshafen, for the nitrogen extraction according to the Birkland-Eyde electric system. In order to secure the needed amount of current for working the process on a large scale there will be erected a large hydraulic plant at Svaegfos which will provide 45,000 horsepower, with a 150-foot dam, using a water flow of 1,200 cubic yards per second. The hydro-electric station will be located in a narrow gorge at the foot of a rocky precipice, and the water will be led to the four turbines of the plant by four flumes cut in the rock instead of by penstocks. Each of the turbines has a capacity of 12,000 horse-power and they are furnished by the Heidenheim works.

TRADE NOTES AND FORMULÆ.

To Repair Rubber Hose When Cracked.—The cracks, previously cleaned, are to be filled with the following solution: 20 parts of gutta percha, 40 parts of caoutchouc, 10 parts of isinglass, 160 parts of sulphide of carbon. Very wide, gaping slits may be plastered with the solution in layers and the slit drawn together with a string. Allow 1 to 2 days for drying. Then the string can be cut through and the protruding cement trimmed off with a sharp knife, that has previously been dipped in water.

To Make Iridescent Glass.—The glass object, while still on the blowpipe, in a red-hot condition, is introduced into a red-hot mold or muffle but little larger than itself, on the bottom of which has been scattered either a mixture of 2 parts of tin salts, 1 part of chloride of barium or chlorate of barium or carbonate of barium, and 0.5 part of carbonate of strontia. The object is turned in all directions and then placed in the cooling furnace. Strontia produces chiefly red tones, baryta the blue, and tin the opal tints or whitish blue color tones.

Utilization of the Sweepings in Gold Workers' Workshops.—The sweepings consist of the dirt that accumulates in gold workers' workshops and contain, in addition to dust, gold, silver, and other metals, with which gold or silver are alloyed. The sweepings are burned with the addition of some saltpeter, in a red hot crucible, the residue is leached with water, dried and melted with the addition of 2 per cent of anhydrous borax. The metallic substance obtained is dissolved in nitro-muriatic acid (aqua regia); the precipitate thus obtained consists of chloride of silver and is treated for silver. The solution in the nitro-muriatic acid is so thoroughly evaporated that it commences to be thick and is then diluted with water and a polished sheet of copper is placed in the fluid, causing the gold to be separated as a brownish powder, which may be filtered, washed, dried and melted with some borax, whereby we obtain a lump of pure gold.

Protective Covering for Glass Ware to be Engraved.—*a.* Photographic process based on the use of carbon paper. Dip a piece of paper in a 4 per cent solution of potassium bichromate, dry it in the dark and insulate it under a negative. To stick the insulated design on the glass, proceed as follows: The carefully-cleaned glass object is coated with a solution of (1) chrome alum 1 part, 30 parts warm water; (2) gelatine 10 parts, warm water 500 parts; then it is dried. The carbon-paper is allowed to soften in cold water for a few minutes and then it is pasted on the carefully cleaned glass which is destined to be engraved (by the sand blast). Develop and heat to 97.5 deg. F. When the picture thus produced is dry, it must be immersed, for a quarter of an hour, in a 4 per cent solution of chrome alum, after which it is again washed and dried. After this pour over the picture a mixture of equal quantities of water and glycerine and dry it, after a time, with blotting paper. The design will now be found in a proper condition for engraving.

Graining Watch Parts of Brass.—This process consists in providing them with a matt granular surface. The object is secured with flat-topped pins on cork disks and brushed with a paste made of water and the finest pumice stone powder. It is then well washed and placed in a solution of 10 parts of water, 0.002 part nitrate of mercury, and 0.004 part sulphuric acid. It is then washed and treated with the graining powder. (This consists of silver powder, tartaric acid and common salt, finely pulverized, mixed at moderate heat.) Following are the ordinary proportions of same:

Silver powder	28	28	28
Tartaric acid	283	110-140	85
Common salt	900	370	900

The powder is moistened with water and spread on the object. The object, with its cork support, is placed in a shallow dish and the paste rubbed on with a stiff brush, the dish being constantly turned. From time to time new quantities of graining powder are added. Wash off with water and treat it with the scratch brush, using a decoction of soap wort.

TABLE OF CONTENTS.

PAGE

I. AERONAUTICS.—The Cornu Helicopter.—4 illustrations ... 316

II. ELECTRICITY.—Elements of Electrical Engineering.—XVII.—By A. E. WATSON, B.E., Ph.D.—10 illustrations ... 302

III. MATHEMATICS.—The Eye of Mathematics.—By Prof. CASSIUS J. KEYSER ... 311

IV. MINING AND METALLURGY.—Malleable Castings by a New Process ... 306
Washing and Coking Tests of Coal ... 305
Formation of Mineral Veins.—III.—By Dr. WILLIS EUGENE EVERETTE.—1 illustration ... 310

V. MISCELLANEOUS.—The Edison Concrete House.—By PERCY H. WILSON ... 310
Losses Resulting from Bad Weather ... 311
Magnitude of the Lighting Industries.—By E. L. ELLIOTT ... 314
Theory of Mirage ... 316

VI. PHOTOGRAPHY.—Green Ammonio-Citrate of Iron for Preparing Blue-print Paper.—By RANDOLPH BOLLING ... 307

VII. PHYSICS.—Life of a Radio-active Element.—By A. T. CAMERON ... 315
Gases and Vapors.—By Prof. O. N. WITT ... 315
How the Earth is Weighed.—By Prof. POYNTING ... 316

VIII. TECHNOLOGY.—Denatured Alcohol from Currants ... 311
Brazilian Copal Gum ... 316
The Colburn Window-Glass Machine.—10 illustrations ... 316